10. IDENTIFICATION AND SCREENING OF TECHNOLOGIES

The objective of this section is to identify and screen potentially applicable technology types and process options which will be developed into candidate remedial alternatives for three Operable Unit (OU) 1-10 media: radionuclide-contaminated soils, nonradionuclide-contaminated soils, tanks, and tank contents. Technology types are a group of operations with common characteristics or results. Examples of technology types include physical separation, stabilization, and capping. A process option is a specific type of operation within a technology type which has a narrow focus for its application, e.g., flotation and screening are process options for the physical separation technology.

Potentially applicable, media-specific technologies and process options are identified in this feasibility study (FS) for each of the general response actions (GRAs) using a focused approach. Technologies and response actions demonstrated to be effective for sites with similar contaminants and contaminated media types, and in particular those demonstrated at Idaho National Engineering and Environmental Laboratory (INEEL), are used to define applicable technologies and process options. This focused approach facilitates the selection of appropriate remedial actions while eliminating the high cost and long schedule involved with evaluating all technologies that may potentially apply.

Remedial technology types and process options were identified and screened based on effectiveness, implementability and cost. Both conventional and innovative and emerging technologies that have been demonstrated at the pilot scale are considered. The effectiveness evaluation focuses on the potential effectiveness of each process option in remediating the volume of waste media and in meeting the remedial action objectives (RAOs) with regard to protecting human health. Specific information considered includes types of contamination and concentration, volume of contaminated media, and rates of collection/removal of liquids or solids. Each process option was classified as being either highly effective, moderately effective, limited, or not effective.

Consideration of implementability includes both technical and administrative feasibility of the technology. Technical implementability includes consideration of technology-specific parameters that constrain effective construction and operation of the technology, with respect to site-specific conditions. Administrative implementability includes consideration of ability to obtain required permits for on- and off-site actions; availability of treatment, storage and disposal services; and the availability of equipment and personnel required to implement the technology.

Consideration of cost includes relative estimates of capital and operation and maintenance costs. Engineering judgment is used to estimate costs as high, moderate, or low; relative to other process options in the same technology type for each medium of concern.

The identification and screening process for remedial technologies at OU 1-10 is summarized in the following subsections. The discussion is organized by contaminated media types: radionuclide-contaminated soils (Section 10.1), nonradionuclide-contaminated soil (Section 10.2), and tank contents (Section 10.3 and 10.4).

10.1 Technology Evaluation For Radionuclide-Contaminated Soils

This section discusses the identification and screening process for soils contaminated with radionuclides at OU 1-10. Figure 10-1 summarizes results of the technology screening process. Potentially applicable technology types and process options are discussed for each GRA as identified in Section 9.4.

10.1.1 No Action

The No Action GRA does not involve active remedial activities beyond site access controls and/or environmental monitoring currently conducted at INEEL as part of site-wide activities. Examples of these include site access controls in the form of fences or caution tape which are designed to prevent exposure to contaminants in soil at the sites of concern. Environmental monitoring is included to enable identification of potential contaminant migration or other changes in site conditions that may warrant future remedial actions. The No Action GRA may not achieve RAOs established for OU 1-10; however, it is retained to serve as a baseline for evaluating remedial action measures.

Site access controls as described in Section 8.0 would be maintained. Environmental monitoring would be conducted through the existing INEEL site-wide program. Monitoring activities may consist of the collection and analysis of air, groundwater, soil, biota, and other media from the site as applicable. Air monitoring may include the use of high- and low-volume air samplers to determine if fugitive radionuclides escape sites where contaminated surface soils exist. Groundwater monitoring may include monitoring contaminant migration in groundwater beneath the site. Soil monitoring would include radiation surveys over and around sites where contaminated soil and debris are left in place, to evaluate if radionuclides have been mobilized to the surface.

Potentially, all of these technologies would be technically and administratively implementable. Costs of soil and air monitoring would be moderate, while groundwater monitoring costs would be slightly higher. All monitoring technologies shown in Figure 10-1 pass the screening process and will be considered further in the FS.

10.1.2 Institutional Controls

Institutional controls are ongoing actions taken to minimize potential threats to human health and the environment. Institutional controls would be maintained while the responsible authority is in control of the site. Based on the *INEL Comprehensive Facility and Land Use Plan* (DOE-ID 1996) institutional controls will be maintained for a minimum of 100 years following site closure. To remain consistent with the baseline risk assessment (BRA), the 100-year institutional control period is assumed to begin in 1998. Institutional controls include legal access restrictions (i.e., deed restrictions) and physical access restrictions (e.g., fencing).

10.1.2.1 Deed Restrictions. A deed restriction is a legally binding deed notice that limits the available use of and activities which can be performed at a given site. These restrictions prevent the completion of exposure pathways that would result in an unacceptable risk to human health. Zoning regulations are one form of deed restrictions and are the primary vehicle for specifying appropriate land use.

GRA	TECHNOLOGY/ PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
No Action	Environmental Monitoring	No additional activities beyond those currently conducted for INEEL site-wide requirements.	No action must be evaluated as a baseline alternative pursuant to the NCP.
Institutional Controls	Deed Restrictions	Deed restrictions on present and future land use; may include special building permit requirements.	Potentially applicable if impacted soils remain on-site.
	Access Restrictions	Prevent physical access to the site using signs, fencing, physical structures (e.g., embankments), or security measures.	Potentially applicable if impacted soils remain on-site.
Containment	Engineered Barriers	Basalt cobbles, gravel, and rock armor are placed over impacted soils.	Potentially applicable to prevent exposure to impacted soils.
	Native Soil Cover	Ten-foot layer of native soil is placed and compacted over impacted soils.	Potentially applicable to prevent exposure to impacted soils.
In Situ Treatment	Vitrification	Thermal conversion of in-place soils to stable glass-like monolith.	Low effectiveness to additionally reduce radionuclide mobility; low implementability due to technical complexity of process.
	Stabilization with Mechanical Mixing	Addition of physical and chemical ammendments to soils producing a stable, leach-resistant wasteform.	Low effectiveness to reduce direct radionuclide exposure, limited additional benefits to immobilize contaminants. Uncertain implementability.
	Soil Flushing	Application of chemical leaching or solubilizing (ACT*DE*CON) agents to remove radionuclides from soil.	Low and uncertain effectiveness to mobilize Cs-137 in soils. Uncertain implementability at the full-scale.
	Biological Treatment	Surface vegetation used to remove and recover radionuclides from soil through plant root systems.	Uncertain implementability and effectiveness for OU 1-10 sites.
	Electrokinetics	Electrodes placed in situ to induce electromigration of contaminants.	Low and uncertain effectiveness to mobilize Cs-137 in soils. Uncertain implementability.

Note: Double lines represent a technology or process option screened from further consideration

Figure 10-1. Technology screening summary for radionuclide-contaminated soil.

GRA	TECHNOLOGY/ PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
Ex Situ Treatment	Physical Separation Screening	Reduce volume of contaminated soils by physical separation of fines from coarse soils by screening.	Technology not demonstrated to effectively reduce volumes of Cs-137 bearing INEEL soils.
	Physical Separation Flotation	Reduce volume of contaminated soils by physical separation of fines from coarse soils by flotation.	Technology not demonstrated to effectively reduce volumes of Cs-137 bearing INEEL soils.
	Physical Separation Attrition Scrubbing	Mechanical agitation used to remove surface contamination from soil particles.	Technology not demonstrated to effectively reduce volumes of Cs-137 bearing INEEL soils.
	Physical Separation Gamma Monitors	Gamma spetroscopy used to separate soils on the basis of activity levels.	Technology not demonstrated to be effective for separating gamma- and alpha-emitting soils at relatively low OU 1-10 soil concentrations.
	Plasma Torch Treatment	Thermal conversion of excavated soils to stable glass-like monolith using a plasma torch process.	Technology not demonstrated at full-scale. Costs are high.
	Stabilization	Addition of physical and chemical ammendments to excavated soils producing a stable and/or solidified, leach-resistant form.	Limited effectiveness to additionally reduce radionuclide mobility. Increased volume of material requiring handling.
	Soil Washing	Chemically extract contaminants from excavated soils	Low effectiveness to mobilize Cs-137 in soils. Uncertain implementability at the full-scale.
Removal	Excavation With Conventional Equipment	Soil excavation with conventional earthmoving equipment such as backhoes and dozers.	Demonstrated effective for the removal of soils to 6.1 m (20 ft) depths at INEEL.
	Excavation With Robotics	Soil excavation using robotic equipment.	Not globally demonstrated to be effective and implementable at INEEL. High costs relative to conventional equipment.
Disposal	On-Site at RWMC	Disposal at the INEEL RWMC.	Administrative difficulties for disposal at the RWMC.
	On-Site at WWP 1957 Cell	Disposal at the INEEL WWP 1957 Cell.	Implementability concerns due to limited remaining capacity.
	On-Site at Proposed ER INEEL Soil Repository	Disposal on-site at the proposed ER INEEL soil repository.	Effective in protecting human health and the environment, and meeting RAOs.
	Off-Site at Permitted Low-Level Waste Disposal Facility	Disposal off-site at a the Environcare low-level radioactive waste disposal facility.	Effective in protecting human health and the environment, and meeting RAOs.

Note: Double lines represent a technology or process option screened from further consideration

Figure 10-1. (continued).

Deed restrictions could possibly achieve RAOs at some sites as a standalone technology and could be used in conjunction with other technologies to meet RAOs at other sites. This option is readily implementable, and costs associated with deed restriction are relatively low. Deed restrictions have been retained for further evaluation in the FS.

10.1.2.2 Access Restrictions. Fencing is a representative type of access restriction. Fencing involves enclosing individual or contiguous areas within a fence with a locking gate. This institutional control reduces risks to human health by limiting exposure to contaminants in soil. It is a viable technology for contamination that is not likely to become airborne. Signage is typically placed at the site to indicate restricted access.

Fencing could achieve RAOs at some sites as a standalone technology and could be used in conjunction with other technologies to meet RAOs. This option is readily implementable, with relatively low costs. Fencing has been retained for further evaluation in the FS.

10.1.3 Containment

Containment refers to remedial actions taken to isolate contamination from the accessible environment. Isolation of contamination eliminates potential exposure pathways to human receptors. Containment technologies evaluated under this GRA include engineered barriers and native soil covers.

10.1.3.1 Native Soil Cover. This cover type consists of approximately 3.05 m (10 ft) of native INEEL soil (i.e., the assumed residential/ecological receptor exposure depth) compacted in lifts and covered with vegetation, gravel, rip-rap or other media. This design is effective in controlling surface exposures but may not be as effective in inhibiting biointrusion as the engineered cover. Impacts to human health and the environment could likely be minimized to allowable levels through administrative and engineering controls. The cost of this cap is moderate. The native soil cover was retained for further consideration.

10.1.3.2 Engineered Barriers. The representative engineered barrier evaluated for this FS is the "SL-1" cap which was used at Waste Area Group (WAG) 5 Power Burst Facility (PBF)/Auxiliary Reactor Area (ARA) and consists of layers of basalt cobbles underlain and overlain by gravel, with a rock armor surface. This cap was designed to control surface exposures to radionuclides and inhibit biotic intrusion for approximately 400 years. This type of cap was considered to be appropriate for OU 1-10 soils contaminated with radionuclides based on its historical applicability at the INEEL.

This technology is estimated to be highly effective in protecting human health and the environment and meeting RAOs. This cap has been constructed successfully elsewhere at INEEL and is therefore considered highly technically and administratively implementable. The cost of this cap is relatively moderate. The engineered barrier technology was retained for further consideration.

10.1.4 In Situ Treatment

In situ treatment consists of implementing technologies capable of immobilizing or reducing the toxicity or volume of contaminants in situ. In situ treatment options are implemented without significant excavation of contaminated media. Construction requirements may include drilling wells, digging trenches, constructing above-ground process equipment and other activities. In situ treatment options potentially applicable to OU 1-10 sites of concern include vitrification, chemical stabilization, soil flushing, biological treatment, and electrokinetics.

10.1.4.1 In Situ Vitrification. In situ vitrification vitrifies contaminated soils to create a monolithic stable, glass-like mass. Vitrification is achieved by applying large electrical currents to the contaminated area with graphite electrodes placed vertically in the soil. The soil mass bounded by the electrodes is heated to over 2000°F and melted. After cooling the resulting wasteform is a leach resistant glass-like form similar to obsidian.

The effectiveness of this option in reducing risks to human health and the environment and in meeting RAOs is estimated to be high if conducted properly. This option would not significantly reduce risks to human health via direct radiation exposure which is the exposure route of concern for the radionuclide-contaminated soil sites. Toxicity of the radionuclides would not be reduced. Reduction in mobility via leaching and infiltration to groundwater, which is a primary benefit of vitrification, would not substantially reduce risks at OU 1-10. In addition, the volume of contaminated materials would not be significantly reduced.

Since full-scale use of this technology has not been completed for a similar site, implementability of this option is uncertain. Costs are considered relatively high. This option is screened from further consideration due to uncertain implementability at a full-scale, minimal benefits in reducing human health risk, and high costs.

10.1.4.2 In Situ Stabilization Using Mechanical Mixing. This option consists of using large diameter augurs to mix soils in situ at depths to 12.2 m (40 ft) below ground surface (bgs) with both chemical and physical stabilization amendments to produce a stable, leach-resistant wasteform. The effectiveness of this option in reducing risks to human health and the environment and in meeting RAOs is estimated to be low. This option would not significantly reduce risks to human health via direct radiation exposure which is the exposure route of concern for the radionuclide-contaminated soil sites. Toxicity of the radionuclides would not be reduced. Reduction in mobility via leaching and infiltration to groundwater, which is a primary benefit of chemical and physical stabilization, would not reduce risks at OU 1-10. Volume of contaminated materials would be increased.

Implementability of this option is uncertain given site-specific conditions. In situ stabilization is technically implementable for OU 1-10 soil contamination. However, in situ stabilization has not been tested at full-scale at INEEL. Costs are considered relatively high. This option is screened from further consideration due to low effectiveness for additional immobilization of the radionuclides present and its effect in reducing human health risk, uncertain implementability, and high cost.

10.1.4.3 In Situ Soil Flushing. This process uses infiltration galleries or injection wells to advect extraction fluids through contaminated soils in situ. Hydraulically downgradient wells recover the fluids for separation of the contaminants and reuse. The effectiveness of this option in reducing risks to human health and in meeting RAOs is considered moderate depending upon site-specific subsurface conditions. However, Cs-137 is essentially immobile under typical soil flushing conditions, and would not be effectively recovered. This option would have limited success in reducing or eliminating risks to human health from OU 1-10. In addition, soil flushing creates a secondary waste stream requiring handling. Toxicity of the radionuclides would not be reduced.

Soil flushing, in combination with physical separation, has previously been tested at bench-scale on Test Reactor Area (TRA) Warm Waste Pond (WWP) sediments with poor results [Idaho National Engineering Laboratory (INEL) 1991]. In situ soil flushing adds complexity due to the requirement for hydraulic control over the extractant fluid and difficulties in uniformly contacting the extractant fluid with contaminated media. Costs are considered moderate relative to other in situ treatment technologies. This option is screened from further consideration due to low effectiveness for the radionuclides present.

10.1.4.4 In Situ Biological Treatment. Phytoremediation is an innovative/emerging technology that uses surface vegetation to uptake toxic metals and radionuclides through roots. Vegetation types may include grasses, shrubs, and/or trees. Metals incorporated in biomass may be recovered by harvesting the vegetation and incinerating the biomass. Incinerator residuals would require disposal in a low level radioactive waste landfill.

Effectiveness and technical implementability of this technology are both very site-specific. Effectiveness of this technology for OU 1-10 sites of concern is uncertain. Arthur (1982) observed radionuclide uptake in INEEL vegetation including Russian thistle, crested wheatgrass, and gray rabbitbrush growing on waste disposal sites. However, this technology has not been demonstrated at the INEEL for remediation of radionuclide-contaminated soils. Immobile contaminant species such as Cs-137 are likely not recoverable by this method. Technical implementability of this technology is also uncertain. If non-arid climate vegetation species were used, supplemental irrigation would likely be required, potentially mobilizing other contaminants. Costs of this technology are estimated as low, relative to other in situ treatment technologies. Impacts to human health and the environment would be minimal. This option is screened from further consideration due to uncertain effectiveness and technical implementability.

10.1.4.5 In Situ Electrokinetics. Electrokinetics is an innovative and emerging technology undergoing development for treatment of radionuclide and non-radionuclide (primarily heavy metals) contaminated soils. Electrodes are placed in situ and used to create a electrical field which results in electromigration of contaminant species. Pre- and post-treatment may be required to enhance effectiveness thus potentially generating additional waste streams. Given the naturally elevated metals concentrations in the INEEL soils, it is questionable that this process option would be effective. At present, electrokinetic remediation is not fully understood because of the many parameters that effect the process (i.e., the presence of buried metallic conductors; immobilization of metal ions by undesirable chemical reactions with naturally occurring and/or co-disposed chemicals; pH and oxidation/reduction changes induced by the process electrode reactions). Chemicals that sorb strongly to soil are not considered conducive to this technique and effectiveness is dependent upon major cation (i.e., Ca, Fe) occurrence. This option is screened from further consideration due to uncertain effectiveness.

10.1.5 Ex Situ Treatment

Ex situ treatment options are performed on excavated contaminated media. Several treatment options for INEEL soils and sediments, including physical, and chemical and thermal technologies, have been investigated at bench and in some cases pilot scale. The objectives of treatment at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites are primarily to reduce the toxicity, mobility, and volume of contaminated media. Toxicity of radionuclides is only reduced by natural radioactive decay. Mobility of contaminants is not a primary concern at OU 1-10 sites, but may pose adverse impacts ecological receptors. Volume reduction would therefore be the primary benefit of treatment of OU 1-10 contaminated soils and sediments.

Effectiveness of many soil treatment options is very site-specific and depends on soil textural classification, mineralogy, chemistry, and many other factors. Evaluations of effectiveness of treatment options in this FS therefore focus on those technologies that have been demonstrated to potentially reduce contaminated soil and/or sediment volumes. Ex situ treatment options potentially applicable to OU 1-10 sites of concern include screening, flotation, attrition scrubbing, gamma monitors and conveyor and gate system, plasma torch treatment, solidification, and soil washing. Each of these are described in the following subsections.

10.1.5.1 Physical Separation By Screening. This technology takes advantage of the typical tendency of radionuclides to be distributed more into soil fines (silts and clays) than into coarse components (coarse sands, gravel, and cobbles). Excavated contaminated soils can be passed through progressively finer screen sizes, using grizzly shakers or other standard process equipment, to separate fine-grained from coarse grained fractions. This technology may be used alone, or in combination with other treatment technologies to reduce the volume of contaminated soils for disposal.

This technology was tested in treatability studies using TRA WWP sediments and soils (INEL 1991). Tests determined that this process is effective at separating fine-grained from coarse grained fractions. However, the effectiveness of screening in reducing the volume of contaminated soils is likely to be limited, because Cs-137 in WWP sediments and soils apparently is not sufficiently concentrated in the fine-grained fraction to result in separation of a soil fraction that could be returned to the site. Results indicated approximately 30% of the total cesium present was in +8 mesh material (gravel and cobbles), which represented at least 60% by weight of the WWP sample sediments.

This option is technically implementable using standard process equipment. Costs are relatively low. However, this technology is screened from further consideration on the basis of low effectiveness.

10.1.5.2 Physical Separation By Flotation. Flotation separates fine-grained from coarse-grained soils by increasing their differences in settling velocities in water a clarifier. The soils would be added to a conical tank filled with water, and air introduced into the tank through diffusers or impellers. The bubbles attach to the particulates, and the buoyant forces on the combined particle and air bubbles are sufficient to cause fine-grained particles to rise to the surface where they can be recovered by skimmers. Coarse-grained materials are removed from the bottom of the tank.

This technology was tested in treatability studies using TRA WWP sediments and soils. Tests determined that this process is effective at separating fine-grained from coarse grained fractions. However, the effectiveness of flotation in reducing the volume of contaminated soils is likely to be limited, since Cs-137 in WWP sediments and soils was not sufficiently concentrated in the fine-grained fraction to result in a separate soil fraction that could be returned to the site. This technology may also produce a secondary liquid wastestream.

This option is technically implementable using standard process equipment. Costs are relatively low. However, this technology is screened from further consideration on the basis of low effectiveness.

10.1.5.3 Physical Separation Using Attrition Scrubbing. Attrition scrubbing consists of mechanical agitation of soil and water mixtures in a mixing tank to remove contaminants bound to particle external surfaces. This technology was determined to be ineffective for Cs-137 removal from WWP sediments and soils (INEL 1991), because only 18% of the Cs-137 was found to be associated with phases in and on the sediment particle coatings. The remaining 82% was determined to be associated with the particle internal mineral lattice structure and could be removed only by dissolution of the particle. However, it was concluded that this technology, combined with screening, could be potentially effective for soils with initial activities within 10 times the allowable level, i.e., 233 pCi/g. Further treatability studies on representative samples from OU 1-10 radionuclide-contaminated soil would be required to determine the effectiveness of this technology, alone or in combination with others, to reduce the volume of contaminated soils.

The effectiveness of attrition scrubbing for reducing the volume of contaminated materials at OU 1-10 sites is low to uncertain and produces a secondary liquid wasteform. Therefore this technology is screened from further consideration.

10.1.5.4 Physical Separation Using Gamma Monitors and Conveyer and Gate System. This technology combines a feed hopper, conveyer belt, gamma spectroscopy and a gate to separate soils moving on the belt on the basis of activity. This technology is currently under evaluation at the INEEL Pit 9 removal and treatment project, to reduce the volume of excavated material requiring treatment prior to final disposal. Materials above and below allowable contaminant levels are diverted to different outlets. Soils with contaminant concentrations below allowable levels could be returned to the excavation, while soils with contaminant concentrations above allowable levels could be treated further, or directly disposed at an appropriate landfill.

The effectiveness of this technology for OU 1-10 soils and sediments is uncertain. This technology has been successfully demonstrated to reduce volumes of radionuclide-contaminated soils at several sites, and is currently being tested for the INEEL Pit 9 project. This technology does not produce secondary wastestreams and uses conventional material-handling equipment. Gamma radiation detectors may be either germanium or sodium iodide. The gamma monitoring-conveyer and gate system is most effective when combined with other technologies in a treatment train, for example vitrification, to stabilize the soils and sediments containing the highest activities. This option has been tested on discreet particles of high-level alpha emitters at Johnston Atoll, and moderate levels (i.e, 100 pCi/g) of gamma emitters in soil at Hanford. Additionally, given the assumption of essentially homogenous contamination across the radionuclide-contaminated soil sites, this technology has limited benefit.

This technology is not readily implementable for OU 1-10 radionuclide-contaminated soils and development costs would be high. This technology has been screened from further consideration in the FS.

10.1.5.5 Plasma Torch Treatment. This option would consist of vitrifying excavated, radionuclide-contaminated soil at high temperatures to produce a stable, glass-like inert waste form. No reduction in radioactivity would occur, therefore proper on-site or off-site disposal would be required. Additionally, this option alone would not reduce risks due to direct radiation exposure if treated materials remained on-site. Toxicity of the radionuclides would not be reduced although it would reduce the volume. However, availability of radionuclides and exposure to environmental receptors would be reduced and the volume of contaminated material would be reduced. Mobility via leaching and infiltration to groundwater would be reduced. This technology may potentially improve the effectiveness of separation technologies by providing a stable wasteform for disposal of relatively high concentration solids. However, it is unlikely if any soil fractions from separation processes would be of high enough activity to require stabilization prior to disposal. This technology therefore offers little improvement in effectiveness over excavation and disposal alone.

Plasma torch vitrification is planned to be demonstrated for treatment of Pit 9 materials at the INEEL, and may be part of the projected INEEL Advanced Waste Treatment Facility (AWTF); however, has not been demonstrated to date. Implementability of this option is considered moderate, if the Pit 9 project or the AWTF is available for use. The status of both projects is uncertain. Implementability is considered low due to the technical complexity of the plasma torch process. Costs would be moderate to high, depending on whether or not the capital construction costs of the melter were borne by INEEL programs, or only by OU 1-10. This option is screened from further consideration on the basis of limited additional effectiveness of reducing direct radiation exposure and the uncertainty of success.

10.1.5.6 Stabilization. This option would consist of adding chemical amendments such as polymers, pozzolons, calcium or sodium silicates, or other amendments to excavated soils to produce a solidified and/or stable wasteform. This option alone would not reduce risks due to direct radiation exposure, which is the primary risk at the OU 1-10 radionuclide-contaminated soil sites of concern. Toxicity of the radionuclides would not be reduced. No reduction in activity would occur, therefore proper on- or off-site disposal of the wasteform would be required. Mobility via leaching and infiltration to groundwater, which is a primary benefit of stabilization, would be reduced. However, volume of contaminated materials would increase by 10 to 20%, depending on results of treatability tests.

This technology might potentially improve the effectiveness of separation technologies by providing a stable wasteform of relatively high concentration solids for disposal. However, it is unlikely any soil fractions from separation processes would be of high enough activity to require stabilization prior to disposal. As a result, this technology offers little improvement in effectiveness over excavation and disposal alone.

The implementability of this option is considered moderate. Extensive handling and mixing of the soils would be required to produce a homogeneous wasteform. Conventional construction and soil handling equipment could be used. Treatability studies would be required to define correct amendments, concentrations, mixing times, etc. Costs would be low to moderate, relative to other ex situ treatment options. This option is screened from further consideration due to low additional effectiveness of reducing direct radiation exposure and because volumes of contaminated media would likely increase.

10.1.5.7 Soil Washing. This option would consist of chemically extracting contaminants from excavated soils and debris to produce clean soils and concentrated residuals. Clean soils would likely be returned to the site of concern, and concentrated residuals would be properly disposed either at an on-site or off-site landfill. Concentrated acids are the most likely extractants. Another process, the ACT*DE*CON™ process was also considered.

Soil washing using concentrated nitric acid, in combination with physical separation, has previously been tested at bench-scale on TRA WWP sediments with poor results. Although Cs-137 removal efficiency for WWP sediments for the greater than +8 mesh fraction (gravels and cobbles) exceeded 90%, Cs-137 activity in the treated solids still exceeded the 690 pCi/g WWP treatment goal [INEL 1991; INEL 1993, Lockheed Martin Idaho Technologies Company (LMITCO) 1995]. Therefore little or no volume reduction of contaminated materials would be expected using this combination of technologies for OU 1-10 soils.

Note that the TRA treatability studies were performed on only two WWP samples. Other native soils and disposal pond sediments at TRA may be different in composition and mineralogy, but would likely be relatively similar. OU 10-06 soils, which were collected from various locations on the INEEL, could be characterized but are likely to be less similar OU 1-10 soils.

The ACT*DE*CON process involves in situ treatment by soil washing to chemically dissolve contaminants. The process solutions are aqueous based and the process itself combines established carbonate recovery chemistry with a chelant and oxidant. The extracted solution then requires processing to concentrate contamination for solution reuse. The concentrated contaminant waste stream then requires treatment, stabilization, and/or disposal. Literature on the application and effectiveness of the process with respect to cesium-137 was not identified. As a result the effectiveness is unknown. However, given the results of previous INEEL soil washing studies and the assumed behavior of cesium-137 in INEEL soils (i.e., cesium-137 incorporates into the clay lattice) the process would not be predicted to be particularly successful. This option is screened from further consideration due to uncertain effectiveness.

This technology does not reduce the toxicity of the radionuclides. Also, this technology would produce secondary wastestreams requiring treatment. This process option is estimated to have low to moderate effectiveness for reducing risks to human health and meeting RAOs at OU 1-10. This option would likely not significantly improve protection of human health and the environment at OU 1-10 soils based on tests conducted at other INEEL sites. The implementability of this option is considered low. Costs are considered moderate relative to other ex situ treatment technologies. This option is screened from further consideration due to low effectiveness.

10.1.6 Removal

The removal GRA consists of excavation of contaminated soils for treatment or disposal at an approved facility. Removal options evaluated for OU 1-10 sites include excavation with conventional earth moving equipment and excavation using robotics.

10.1.6.1 Excavation With Conventional Earthmoving Equipment. Excavation with backhoes and dozers represents standard excavation techniques using conventional equipment. Conventional earth moving equipment has been demonstrated to be completely effective for removing contaminated soil to depths of up to 6.1 m (20 ft bgs) at the INEEL. Equipment operators can be shielded in positive pressure cabs as needed to reduce exposures during excavation. Impacts to human health and the environment during removal activities could likely be minimized to allowable levels through administrative and engineering controls. These process options are therefore considered technically and administratively feasible. Costs are considered relatively low. These process options are retained for further consideration

10.1.6.2 Excavation With Robotics. Excavation using robotics represents non-standard excavation techniques using remotely-operated equipment. While these technologies have been demonstrated at INEEL, robotics have not been globally demonstrated to be effective and implementable, and would require a site-specific evaluation. This technology would reduce worker exposures, based on previous INEEL experience with contaminated site excavation; however, costs are considered relatively high. This technology was therefore screened from further consideration.

10.1.7 Disposal

Disposal options include several INEEL locations and an off-site low-level waste facility. The INEEL disposal locations include the Radioactive Waste Management Complex (RWMC), the WWP 1957 cell, and a proposed Environmental Restoration (ER) INEEL soil repository.

10.1.7.1 Disposal at RWMC. Disposal at the RWMC is determined to be completely effective in protecting human health and meeting RAOs. This option has been used for prior INEEL CERCLA actions and is therefore considered readily technically feasible; however, costs would be relatively high. Currently, RWMC operations discourage disposal of low-level radionuclide-contaminated soils. Therefore, due to high costs and potential administrative difficulties dealing with waste acceptance criteria, disposal at RWMC is not retained.

10.1.7.2 Disposal at WWP 1957 Cell. Disposal at the WWP 1957 cell is regarded as effective in protecting human health and meeting RAOs, if the pond is closed to meet these objectives. This option has been used for prior INEEL CERCLA Removal Actions and Interim Actions and is therefore considered technically and administratively feasible for disposal. However, remaining disposal capacity would likely not be sufficient to contain OU 1-10 contaminated soil volumes. Costs are estimated to be relatively low. Based on the limited disposal capacity remaining, this disposal option is not retained for further consideration.

10.1.7.3 Disposal at Proposed ER INEEL Soil Repository. Currently a landfill for INEEL low level radionuclide-contaminated soil and debris is proposed as part of the ER program at INEEL. While the current status of this facility is uncertain, disposal costs would likely be much lower than current RWMC disposal fees. Although the timeframe associated with construction of the facility and its waste acceptance criteria are uncertain at this time, this option has been retained for further evaluation.

10.1.7.4 Disposal at Permitted Off-Site Low-Level Waste Disposal Facility. This option is considered highly effective in protecting human health and the environment and in meeting RAOs. The Envirocare facility, located approximately 480 km (300 mi) from INEEL, has been previously used for disposal of radionuclide-contaminated soils and was selected as a representative off-site disposal location for costing purposes. Impacts to human health and the environment could likely be minimized to allowable levels through administrative and engineering controls during transportation from INEEL to the facility. This process option is therefore considered technically and administratively implementable, assuming the Envirocare facility maintains its permit for low-level waste disposal. Costs for this option are estimated to be relatively moderate. Disposal off-site has been retained for further consideration.

10.2 Technology Evaluation For Nonradionuclide-Contaminated Soils

This section discusses the identification and screening process for nonradionuclide-contaminated soils at OU 1-10. The nonradionuclide contaminants of concern identified at the sites of concern within OU 1-10 consist of lead, mercury, and total petroleum hydrocarbons (TPHs). Figure 10-2 summarizes the results of the screening process. Technology types and process options potentially applicable to the nonradionuclide contaminants at OU 1-10 are discussed under their respective GRAs in the following subsections.

10.2.1 No Action

The No Action GRA does not involve remedial activities beyond site access controls and/or environmental monitoring currently conducted at INEEL as part of site-wide activities. Examples of these site access controls in the form of fences or caution tape which are designed to prevent exposure to contaminants in soil at the sites of concern. Environmental monitoring is included to enable identification of potential contaminant migration or other changes in site conditions that may warrant future remedial actions. The No Action GRA may not achieve RAOs established for OU 1-10, however, it is retained to serve as a baseline for evaluating remedial action measures.

Site access controls as described in Section 8.0 would be maintained. Environmental monitoring would be conducted through the existing INEEL site-wide program. Monitoring activities may consist of the collection and analysis of air, groundwater, soil, biota, and other media from the site as applicable. Air monitoring may include the use of high- and low-volume air samplers determine if fugitive metals escape sites where contaminated surface soils exist. Groundwater monitoring may include monitoring contaminant migration in groundwater beneath the site. Soil monitoring might include conducting surveys over and

GRA	TECHNOLOGY/ PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
No Action	Environmental Monitoring	No additional activities beyond those currently conducted for INEEL site-wide requirements.	No action must be evaluated as a baseline alternative pursuant to the NCP.
Institutional Controls	Deed Restrictions	Deed restrictions on present and future land use; may include special building permit requirements.	Potentially applicable if impacted soils remain on-site.
	Access Restrictions	Prevent physical access to the site using signs, fencing, physical structures (e.g., embankments), or security measures.	Potentially applicable if impacted soils remain on-site.
Containment	Native Soil Cover	Ten-foot layer of native soil is placed and compacted over impacted soils.	Potentially applicable to prevent exposure to impacted soils.
	Asphalt-/Concrete Cap	Asphalt or concrete placed over areas of impacted soil.	Effective but limits future use of capped areas and has a relatively high cost.
	Clay-/Synthetic Cap	Low-permeability clay, geonet, geotextile, LDPE/HDPE liner materials placed over impacted soils.	Effective but limits future use of capped areas and has a relatively high cost.
In Situ Treatment	Vitrication	Thermal conversion of in-place soils to stable glass-like wasteform.	Low implementability due to technical complexity of process. High relative costs.
	Stabilization with Mechanical Mixing	Addition of physical and chemical ammendments to in-place soils producing a stable, leach-resistant form.	Low effectiveness is reducing direct exposure to contaminants, uncertain implementability for surfical soils.
	Soil Flushing	Addition of chemical agents to mobilize contaminants from soil for recovery and volume reduction.	Uncertain implimentability and effectiveness of full-scale, in situ application at OU 1-10.
	Biological Treatment	Surface vegetation used to remove and recover contaminants from soil.	Uncertain implimentability and effectiveness for OU 1-10 sites of concern.
	Electrokinetics	Electrodes placed in situ to induce electromigration of contaminants.	Low and uncertain effectiveness to mobilize metals in soils. Uncertain implementability.
	Bioventing	Oxygen-enhanced biodegradation.	Uncertain effectiveness for diesel-contaminated soil.

Note: Double lines represent a technology or process option screened from further consideration

Figure 10-2. Technology screening summary for nonradionuclide-contaminated soil.

GRA	TECHNOLOGY/ PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
Ex Situ Treatment	Physical Separation	Reduce volume of contaminated soils by physical separation of fines from coarse soils by screening.	Potentially effective at reducing volume of contaminants in soil.
	Stabilization	Addition of physical and chemical ammendments to excavated soils producing a stable, leach-resistant form.	Potentially effective at reducing mobility of contaminants in soil.
	Thermal Desorption via Retort	Thermal treatment of excavated soils to remove contaminants through volatilization.	Potentially effective at reducing contaminant (mercury) concentrations in soil.
	Soil Washing	Treatment of contaminated soils using physical separation and chemical agents to extract contaminants from soil.	Potentially effective at reducing contaminant concentrations in soil.
	Landfarming	Landfarming allows soil to biologically decay.	Effective for diesel-contaminated soils. Not applicable to lead and mercury.
	Recycling	Asphalt batching plants recyle diesel-contaminated soil.	Implementability difficulties because local vendors do not recycle.
Removal	Excavation With Conventional Equipment	Excavation with conventional earth moving equipment such as backhoes and dozers.	Demonstrated effective for the removal of soils to depths of 6.1 m (20 ft) at INEEL.
Disposal	On-Site at WWP 1957 Cell	Disposal at the INEEL WWP 1957 Cell.	Implementability difficulties due to limited capacity remaining.
	On-Site at ER INEEL Soil Repository	Disposal on-site at the proposed ER INEEL soil repository.	Currently this facility is not expected to accept RCRA hazardous wastes.
	Off-Site at Permitted RCRA TSDF	Disposal off-site at a permitted RCRA treatment, storage, and disposal facility in Arlington, Oregon.	Effective in protecting human health and the environment, and in meeting RAOs.
	On-site at CFA	Disposal with the purposes of landfarming petroleum contaminated soil.	Has been implemented for other INEEL actions. Effective for WRRTF 13 soils only. Not applicable to lead and mercury.

Note: **Double lines represent a technology or process option screened from further consideration**

Figure 10-2. (continued).

around sites where contaminated soil and debris are left in place, to determine if contaminants have been mobilized to the surface.

Potentially, all of these technologies would be technically and administratively implementable. Costs of soil and air monitoring are moderate, while groundwater monitoring costs would be slightly higher. All monitoring technologies shown in Figure 10-2 pass the screening process and will be considered further in the FS.

10.2.2 Institutional Controls

Institutional controls are ongoing actions taken to minimize potential threats to human health and the environment. Institutional controls would be maintained while the responsible authority is in control of the site. Based on the *INEL Comprehensive Facility and Land Use Plan* (DOE-ID 1996) institutional controls will be maintained for a minimum of 100 years following site closure. To remain consistent with the BRA, the 100-year institutional control period is assumed to begin in 1998. Institutional controls include legal access restrictions (i.e., deed restrictions) and physical access restrictions (e.g., fencing).

10.2.2.1 Deed Restrictions. A deed restriction is a legally binding deed notice that limits the available use of and activities which can be performed at a given site. These restrictions prevent the completion of exposure pathways that would result in an unacceptable risk to human health. Zoning regulations are one form of deed restrictions and are the primary vehicle for specifying appropriate land use.

Deed restrictions could possibly achieve RAOs at some sites as a standalone technology and could be used in conjunction with other technologies to meet RAOs at other sites. This option is implementable, and deed restriction costs are relatively low. Deed restrictions have been retained for further evaluation in the FS.

10.2.2.2 Access Restrictions. Fencing is a representative type of access restriction. Fencing involves enclosing individual or contiguous areas within a fence with a locking gate. This institutional control reduces risks to human health by limiting exposure to contaminants in soil. It is a viable technology for contamination that is not likely to become airborne. Signage is typically placed at the site to indicate restricted access.

Fencing could achieve RAOs at some sites as a standalone technology and could be used in conjunction with other technologies to meet RAOs. This option is implementable, with relatively low costs. Fencing has been retained for further evaluation in the FS.

10.2.3 Containment

The Containment GRA refers to the use of a physical barrier (e.g., cover or cap) to eliminate or minimize contact with and/or potential migration of contaminants. Containment technologies evaluated under this GRA include a native soil cover, asphalt-/concrete-based caps, and clay-/synthetic-based caps.

10.2.3.1 Native Soil Cover. This cover type consists of approximately 3.05 m (10 ft) and may include existing native INEEL soil (i.e., the assumed residential/ecological receptor exposure depth) in place at a specific site, compacted in lifts and covered with vegetation, gravel, rip-rap, or other media. This design is effective in controlling human and ecological exposures. Periodic inspections and maintenance (if required) would be conducted to verify the integrity of the soil cover and its effectiveness. Soil covers are readily implementable. The cost of the native soil cover is relatively moderate. The native soil cover was retained for further consideration.

10.2.3.2 Asphalt-/Concrete-based Caps. These cap types consist of the placement of an appropriate thickness of either asphalt or concrete over a specified area of contaminated soil. Asphalt-/ concrete-based caps are effective in controlling human and ecological exposure to contaminants in surface and subsurface soil. In addition, these cap types are effective in mitigating migration of the contaminants in the soil. Periodic inspections and maintenance (if required) would be conducted to verify the integrity of the asphalt-/concrete-based caps and their effectiveness. Asphalt-/concrete-based caps are readily implemented; however, future uses of the capped areas would be limited due to the presence of the caps. The costs associated with the asphalt-/concrete-based caps are moderate to high depending on the material used (i.e., asphalt or concrete) and the thickness of the cap applied. Based on the limited future uses of the capped areas and the relatively high costs, asphalt-/concrete-based caps were not retained for further consideration.

10.2.3.3 Clay-/Synthetic-based Caps. These cap types consist of the placement of low-permeability clay (typically 1 ft) and/or synthetic materials (e.g., geonet, geotextile fabric, and low density polyethylene/high density polyethylene plastic liner) either individually or in multiple layers over a specified area of contaminated soil. Typically a topsoil layer (approximately 1 ft) would be placed on top of the clay or synthetic materials and graded and vegetated to minimize erosion of the cap. The clay-/synthetic-based caps are effective in controlling human and ecological exposure to contaminants in surface and subsurface soil. In addition, these cap types are highly effective in limiting potential migration of the contaminants in the soil. Periodic inspections and maintenance (if required) would be conducted to verify the integrity of the clay-/synthetic-based caps and their effectiveness. Clay/synthetic-based caps are readily implemented; however, as with any cap design, future uses of the capped areas might be limited due to the presence of the caps. For example, heavy construction activities on the cap could create weak areas in the cap, or create complete ruptures, and allow water to move quickly, through the cap material. The costs associated with the clay-/synthetic-based caps are moderate to high depending on the materials used (i.e., low-permeability clay, synthetic materials, or both). Additionally, the primary benefit of clay-/synthetic based caps, when compared to native soil caps, is the clay/synthetic cap's ability to limit the movement of water. As discussed in Chapter 6, none of the WAG 1 surface soil sites are likely to pose a threat to groundwater, so the expected benefit from installing clay/synthetic caps is not expected to justify the additional costs. Based on the limited future uses of the capped areas and the relatively high costs, clay-/synthetic-based caps were not retained for further consideration.

10.2.4 In Situ Treatment

The In Situ Treatment GRA consists of technologies which have the potential to treat soil contamination in place with minimal excavation or removal of the contaminated media. Construction requirements may include drilling wells, digging trenches, constructing above-ground process equipment and other activities. In situ treatment options potentially applicable to lead and/or mercury in soil at OU 1-10 sites of concern consist of vitrification, solidification/stabilization, biological treatment, soil flushing, electrokinetics, and bioventing.

10.2.4.1 In Situ Vitrification. This technology uses an electric current (via graphite electrode or plasma arc) to heat soil materials above their melting point. The current is supplied through a square array of electrodes placed in the ground. As the soil cools, a glass-like monolith forms encapsulating the inorganics.

This technology is effective at encapsulating lead contamination, but is ineffective for mercury and petroleum contamination due to volatilization of these contaminants that is likely to occur unless emission control measures are also utilized. This technology is implementable, but requires proximity to high-capacity electrical power lines. The cost of this technology is relatively high. Due to high costs and limited effectiveness for mercury-contaminated soil, this option is not retained for further evaluation.

10.2.4.2 In Situ Stabilization Using Mechanical Mixing. This option consists of using large diameter augurs to mix soils in situ at depths to 12.2 m (40 ft) bgs with chemical and physical stabilization amendments to produce a solidified, leach-resistant wasteform. The effectiveness of this option in reducing risks to human health and meeting RAOs is highly dependent on the stabilized form of the contaminants after treatment. If the contaminants were stabilized in a form that limited their bioavailability, this option could potentially reduce risks to human health due to homegrown produce ingestion and soil ingestion. Mobility via leaching and infiltration to groundwater would be reduced. The volume of contaminated materials would be increased based on the volume of amendments used.

Implementability of this option is moderate depending on site-specific conditions. In situ stabilization is also administratively implementable. However, in situ stabilization of mercury is not feasible. Also, the contents of the lead contaminated burn pits do not support this type of mixing therefore the option is not retained for further evaluation.

10.2.4.3 In Situ Soil Flushing. This process uses infiltration galleries or injection wells to advect extraction fluids through contaminated soils in situ. Hydraulically downgradient wells recover the fluids for separation of the contaminants and reuse. The effectiveness of this option in reducing risks to human health and in meeting RAOs is considered moderate. This option would reduce or eliminate risks to human health from OU 1-10 sites by chemically removing contaminants for disposal elsewhere. However, this technology creates a secondary waste stream requiring handling.

In situ soil flushing adds complexity due to the requirement for hydraulic control of the extractant fluid and providing uniform contact of the extractant fluid with contaminated media. Costs are considered moderate relative to other in situ treatment technologies. This option is screened from further consideration due to low technical implementability and low effectiveness.

10.2.4.4 In Situ Biological Treatment. Phytoremediation is an innovative/emerging technology that uses vegetation to uptake toxic metals through roots. Vegetation types may include grasses, shrubs, and/or trees. Metals incorporated in biomass may be recovered by harvesting the vegetation and incinerating the biomass. Incinerator residuals would require disposal in a Resource Conservation and Recovery Act (RCRA) landfill.

Effectiveness of this technology for OU 1-10 sites of concern is uncertain. This technology has not been demonstrated at the INEEL or other DOE sites for remediation of nonradionuclide-contaminated soils. Immobile precipitated contaminant species are likely not recoverable by this method however, chelating agents may increase uptake. Technical implementability of this technology is also uncertain. If non-arid climate vegetation species were used, supplemental irrigation would likely be required, which could potentially flush mobile contaminants to depths greater than recoverable. Costs of this technology are estimated as low, relative to other in situ treatment technologies. Impacts to human health and the environment would be minimal. This option is screened from further consideration due to uncertain effectiveness and technical implementability.

10.2.4.5 *In Situ Electrokinetics.* Electrokinetics is an innovative and emerging technology undergoing development for treatment of radionuclide and non-radionulcide (primarily heavy metals) contaminated soils. Electrodes are placed in situ and used to create a electrical field which results in electromigration of contaminant species. Pre- and post-treatment may be required to enhance effectiveness thus potentially generating additional waste streams. Given the naturally elevated metals concentrations in the INEEL soils, it is questionable that this process option would be effective. At present, electrokinetic remediation is not fully understood because of the many parameters that effect the process (i.e., the presence of buried metallic conductors; immobilization of metal ions by undesirable chemical reactions with naturally occurring and/or co-disposed chemicals; pH and oxidation/reduction changes induced by the process electrode reactions). Chemicals that sorb strongly to soil are not considered conducive to this technique and effectiveness is dependent upon major cation (i.e., Ca, Fe) occurrence. This option is screened from further consideration due to uncertain effectiveness.

10.2.4.6 *In Situ Bioventing.* Bioventing is a technology based on the premise that the natural attenuation of petroleum-contaminated compounds can be enhanced by providing oxygen to the subsurface thus stimulating aerobic biodegradation of the contaminants. Implementation of this process option is only applicable to the diesel-contaminated subsurface soils at WRRTF-13. Injection wells are constructed based on estimated zones of influence and oxygen is delivered as air via injection to these wells. Field pilot testing to support design of the well network has been implemented at other sites; however, results regarding the effectiveness of the process were not readily available. Given limited data with regards to the effectiveness of the process and because diesel fuel is composed of high molecular weight hydrocarbons, the effectiveness is presumed to be uncertain. This option is screened from further consideration due to uncertain effectiveness.

10.2.5 Ex Situ Treatment

The ex situ treatment options are performed on excavated contaminated media. Effectiveness of ex situ soil treatment options is site-specific and is dependent upon soil textural classification, mineralogy, chemistry, and other factors. The effectiveness evaluation of ex situ treatment options focus on those with demonstrated success in reducing contaminated soil volumes. Ex situ treatment process options for nonradionuclide-contaminated soils consist of physical separation, stabilization, chemical extraction, and thermal desorption (retorting) and soil washing. Landfarming and recycling are considered with respect to the diesel-contaminated soil at WRRTF-13. Each of these are discussed in the following subsections.

10.2.5.1 *Physical Separation.* Physical separation uses physical processes to reduce the volume of contamination and/or liberate and separate contaminants from the soil matrix. In a typical physical separation process, soil particles are separated into fractions (coarse- and fine-grained) using a physical separation process. Physical separation is achieved through particle size separation, gravity separation, and attrition scrubbing. Typical physical separation processes include scalping (grizzly separator), primary separation (trommel and screens), and secondary separation (jig and concentrator). Physical separation is typically a major component of the soil washing technology. The resulting reduced volume of contaminants can be disposed of appropriately or further treated using other treatment techniques.

The effectiveness of physical separation options for lead is dependent on the assumption that the lead contamination is concentrated in the fine-grained fraction of the soil matrix. Based on observations regarding lead contamination partioning in soil at non-INEEL sites, this assumption is considered valid. Due to the physical properties of mercury and mercury-compounds, the effectiveness of this technology for mercury is considered high. Physical separation has been shown to be effective for both lead and mercury in remediation applications at non-INEEL sites. However, its effectiveness has not been evaluated for lead and mercury in WAG 1 soils. Bench-scale treatability tests would be necessary to fully evaluate the potential effectiveness of this technology on WAG 1 soils. Implementability of physical separation is considered high. Physical separation equipment is readily available. Costs associated with physical separation are relatively low compared to other treatment technologies. Although treatability testing would be required, physical separation is retained for further consideration.

10.2.5.2 Stabilization. This option would consist of adding chemical and/or physical amendments such as polymers, pozzolons, calcium or sodium silicates to excavated soils to produce a stable/solidified wasteform. Typically, the volume of contaminated media can increase from 10 to 30%. This solidified/stabilized wasteform would be disposed of appropriately.

The effectiveness of this option is relatively high for lead-contaminated soils and moderate to low for mercury- and petroleum-contaminated soils, but is highly dependent on the soil characteristics. Volume of materials requiring handling would increase. The implementability of this option is considered moderate to high. Extensive handling and mixing of the soils would be required to produce a homogeneous wasteform. Standard construction and soil handling equipment could be used. Treatability studies would be required to define correct amendments, concentrations, and mixing times, and other specific treatment requirements. Costs would be low to moderate, relative to other ex situ treatment options.

Based on the limited effectiveness of stabilization on mercury- and petroleum-contaminated soils, this option is not retained for the sites of concern with mercury and petroleum contamination. However, this option is retained for further evaluation for sites of concern with lead contamination.

10.2.5.3 Thermal Desorption via Retort. This technology applies specifically to mercury-contaminated soils and sediments. Mercury retorting consists of heating contaminated soil to approximately 1000°F and volatalizing mercury as a vapor. The vapor is subsequently either cooled and the liquid mercury recovered, or passed through activated carbon canisters where the mercury is adsorbed. Process equipment may include, but is not limited to, material handlers including a feed conveyer, heating units, heat exchangers, condensers, and air pollution control equipment including a baghouse, and granular activated carbon adsorbers.

This process has successfully treated soil contaminated with mercury in the 10 to 200 mg/kg range at INEEL at Central Facilities Area (CFA) and Test Area North (TAN) soil residuals that passed the toxicity characterization leaching procedure (TCLP) criteria. Treatment residuals may include mercury-contaminated water vaporized from soil, requiring further treatment prior to disposal. Recovered metallic mercury could be recycled.

Technical and administrative implementability of this technology is considered high, since it has been previously implemented at the INEEL for soil treatment. Costs are relatively moderate. This option is retained for further consideration for sites of concern with mercury contamination.

10.2.5.4 Soil Washing. This option would consist of chemically extracting contaminants from excavated soils to produce clean soils and concentrated residuals. Typical extractants used would consist of acids or other chemical agents to either leach contaminants from the soils matrix or convert them to chemical forms which would be amenable to physical separation processes. The extractant solution would likely be regenerated onsite using precipitation or an ion exchange resin and reused in the chemical extraction process. Extracted inorganics would either be recycled or disposed of appropriately. Chemical extraction is typically a major component of the soil washing technology.

The effectiveness of this option is considered moderate to high for both mercury and lead, and low for petroleum contaminated soils. However, multiple extraction stages and/or high extractant concentrations may be required to meet PRGs, especially for mercury. Treatability studies would be required to evaluate these parameters. Removal of contaminants from the soil would reduce risks human health. Soil washing is implementable. The costs associated with this option are moderate for lead and moderate to high for mercury. Results of treatability studies are required to accurately predict project costs. Due to potentially high costs and the need for treatability studies, this option was not retained for further evaluation for sites of concern with mercury and petroleum contamination. This option is retained for further evaluation for sites of concern with lead contamination.

10.2.5.5 Landfarming. This process option is only applicable to the diesel-contaminated soils at WRRTF-13. Land farming of petroleum-contaminated soils allows the contamination to decay. The chemical and biological induced changes to the composition of the contamination is also known as weathering is enhanced by overturning (i.e., tilling) the contaminated soil. This process option has been previously implemented at the INEEL. Therefore it is considered technically and administratively feasible. Costs are considered low.

10.2.5.6 Recycling. Recycling of petroleum-contaminated soil as a process option includes excavation and transport of the diesel-contaminated soils to an asphalt batch plant for inclusion in their feed material. However, for this option to be considered technically implementable, a vendor that uses these soils in their manufacturing process that is also permitted by the state to do so must be available. Local asphalt supply companies have indicated that they do not use petroleum-contaminated soil in the manufacture of asphalt. Additionally, INEEL does not have a batch plant onsite. This process option is eliminated because it is not technically implementable.

10.2.6 Removal

Removal process options for nonradionuclide-contaminated soil consist of excavation with conventional excavators. This option represents standard excavation techniques. Conventional equipment has been demonstrated to be effective for removing contaminated soil at depths to 6.1 m (20 ft) bgs at the INEEL. Equipment operators wear proper personal protective equipment as needed to reduce exposures during excavation. Impacts to human health and the environment during removal activities could likely be minimized to allowable levels through administrative and engineering controls. This process option is therefore considered technically and administratively feasible. Costs are considered relatively low. Standard excavation techniques are retained for further consideration.

10.2.7 Disposal

Disposal options considered include three on-site disposal options and one off-site disposal option. On-site disposal options include disposal at the WWP 1957 cell, a proposed ER INEEL soil repository, and the CFA land farm. An off-site RCRA-permitted landfill exists approximately 480 km (300 mi) from the INEEL.

10.2.7.1 Disposal at WWP 1957 Cell. Disposal at the WWP 1957 cell is regarded as effective in protecting human health and meeting RAOs, assuming the pond is closed in a manner that meets these objectives. This option has been used for prior INEEL CERCLA Removal Actions and Interim Actions and is therefore considered technically and administratively feasible for disposal. However, remaining disposal capacity would likely not be sufficient for OU 1-10 soils. Costs are estimated as relatively low.

Based on the limited disposal capacity remaining, this disposal option is not retained for further consideration.

10.2.7.2 Disposal at Proposed ER INEEL Soil Repository. Currently a landfill for INEEL low-level radionuclide-contaminated soil and debris is proposed as part of the ER program at INEEL. While the current status of this facility is uncertain, disposal costs would likely be much lower than current RWMC disposal fees. However, the purpose and design of the proposed facility is to accept low-level radionuclide-contaminated soil and debris. Therefore, disposal of nonradionuclide-contaminated soil at the proposed facility would likely be administratively infeasible. Thus, this alternative has not been retained for further consideration.

10.2.7.3 Disposal at the CFA Land Farm. Disposal at the CFA land farm is regarded as effective for the WRRTF-13 petroleum contaminated soils. Land farming of petroleum contaminated soils would allow the petroleum contamination to biologically decay. Land farming of lead and mercury contaminated soils is unlikely to be effective, so it is not considered further. Land farming of petroleum contaminated soils has been used for INEEL CERCLA actions so it is considered to be technically and administratively feasible.

10.2.7.4 Off-Site RCRA Treatment, Storage, and Disposal Facility. This option is considered highly effective in protecting human health and the environment and in meeting RAOs. A facility is located in Arlington, Oregon, and has been previously used for disposal of RCRA-contaminated soils from INEEL. This process option is therefore considered technically and administratively implementable. Costs for this option are estimated as relatively high. This disposal option is retained for further consideration.

10.3 Technology Evaluation For TSF-26 Tank Contents

This section discusses the identification and screening of processes for dealing with the contents of the underground storage tanks (USTs) at OU 1-10 [i.e., Technical Support Facility (TSF)-26 PM-2A V-13 and V-14]. This section addresses the fluid contents of the tanks as well as the solid heel which remains in the tank after any liquid utilized to remove the heel is pumped out. However, as noted in Section 9, the majority of the tank contents and liquid have been removed and the tanks have been filled with diatomaceous earth. It is assumed that liquid, if any, pumped into the tanks can be treated on site prior to the commencement of work on the heel. Figure 10-3 graphically depicts the results of the screening process. The technologies and process options are discussed under the GRA's in the following subsections.

10.3.1 No Action

The No Action GRA does not involve remedial activities beyond site access controls and/or environmental monitoring currently conducted at INEEL as part of site-wide activities. Examples of these site access controls in the form of fences or caution tape which are designed to prevent exposure to contaminants in soil at the sites of concern. Environmental monitoring is included to enable identification of potential contaminant migration or other changes in site conditions that may warrant future remedial actions. The No Action GRA may not achieve RAOs established for OU 1-10, however, it is retained to serve as a baseline for evaluating remedial action measures.

Site access controls as described in Section 8.0 would be maintained. Environmental monitoring would be conducted through the existing INEEL site-wide program. Monitoring activities may consist of the collection and analysis of air, groundwater, soil, biota, and other media from the site as applicable. Air

GRA	TECHNOLOGY/ PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
No Action	No Action	No additional activities beyond those currently conducted for INEEL site-wide requirements.	No action must be evaluated as a baseline alternative pursuant to the NCP.
Institutional Controls	Deed Restrictions	Deed restrictions on present and future land use; may include special building permit requirements.	Potentially applicable if tank contents remain on-site.
	Access Restrictions	Prevent physical access to the site using signs, fencing, physical structures (e.g., embankments), or security measures.	Potentially applicable if tank contents remain on-site.
Containment	Capping	Layers of soil and/or other materials are placed over tank locations to limit direct exposure and precipitation infiltration.	Low effectiveness in preventing potential releases from tanks. May contribute to structural failure of the tanks if integrity is diminished.
	Hydraulic Barriers	Installation of sheet piling, grout injection, or slurry wall to limit horizontal and vertical migration of contaminants	Uncertain effectiveness and high costs are associated.
In Situ Treatment	Physical Treatment	Stabilizing by adding ammendments, or thermal conversion of tank contents to obtain stable wasteform.	Potentially effective in reducing possible releases of tank contents to the environment. Thermal conversion is uncertain with metal tanks.
	Chemical Leaching Treatment	Addition of solvents, acids, chelating agents to selectively dissolve contaminants from tank materials.	Uncertain implementability and effectiveness for tank sites and secondary waste stream generation.

Note: Double lines represent a technology or process option screened from further consideration

Figure 10-3. Technology screening summary for tank contents.

GRA	TECHNOLOGY/ PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
Ex Situ Treatment	Physical Treatment	Dewatering techniques, physical stabilization, vitrification and encapsulation options for liquid and solid tank contents.	All are potentially applicable to tank liquids and solids, except vitrification. Vitrification has uncertain implemetability for the materials expected to be encountered.
	Chemical Treatment	Chemical leaching to extract contaminants and chemical stabilization using various chemical agents.	Chemical leaching not implemetable since additional handling steps are required. Chemical stabilization is potentially applicable.
Removal	Remote Operation	Uses vacuum devices or water/air jets and pumps to remove materials from tanks remotely.	Potentially applicable for tank contents at OU 1-10.
	Direct Operation	Removal of tank contents with conventional equipment such as clam-shell excavators, backhoes and dozers.	Uncertain effectiveness, low implementability, and high costs.
Disposal	On-Site at RWMC	Disposal at the INEEL RWMC.	Administrative difficulties due to discouragement toward disposal of environmental wastes at this facility.
	On-Site at Proposed ER INEEL Soil Repository	Disposal on-site at the proposed ER INEEL soil repository.	Effective in protecting human health and the environment, and in meeting RAOs.
	Off-Site At Permitted Low-Level Waste Disposal Facility	Disposal off-site at the Envirocare low-level radioactive waste disposal facility.	Effective in protecting human health and the environment, and in meeting RAOs.

Note: Double lines represent a technology or process option screened from further consideration

Figure 10-3. (continued).

monitoring may include the use of high- and low-volume air samplers determine if fugitive metals escape sites where contaminated surface soils exist. Groundwater monitoring may include monitoring contaminant migration in groundwater beneath the site.

Actions taken to reduce the potential for exposure are not included. Under present conditions, the tanks and the soil cover over the tanks are intact. Therefore, since the 3.05 m (10 ft) of soil cover provides sufficient shielding the No Action GRA may be protective of human health and the environment. If no further maintenance is performed, the tanks may fail or be breached by accidental intrusion in the future. If the tanks were breached, the risk to human health may be significant.

10.3.2 Institutional Controls

Institutional controls include actions taken by the responsible authorities to minimize potential danger to human health and the environment. Institutional controls are ongoing actions that can be maintained only for as long as the responsible authority is in control of the site. Based on the *INEL Comprehensive Facility and Land Use Plan* (DOE-ID 1996) institutional controls will be maintained for a minimum of 100 years following site closure. To remain consistent with the BRA, the 100-year institutional control period is assumed to begin in 1998. Representative types of institutional control include deed restrictions and land-use restrictions.

10.3.2.1 Deed Restrictions. A deed restriction is a legally binding deed notice that limits the available use of and activities which can be performed at a given site. These restrictions prevent the completion of exposure pathways that would result in an unacceptable risk to human health. Zoning regulations are one form of deed restrictions and are the primary vehicle for specifying appropriate land use.

Deed restrictions could possibly achieve RAOs at some sites as a standalone technology and could be used in conjunction with other technologies to meet RAOs at other sites. This option is implementable, and deed restriction costs are relatively low. Deed restrictions have been retained for further evaluation.

10.3.2.2 Access Restrictions. Fencing is a representative type of access restriction. Fencing involves enclosing individual or contiguous areas within a fence with a locking gate. This institutional control reduces risks to human health by limiting exposure to contaminants in soil. It is a viable technology for contamination that is not likely to become airborne. Signage is typically placed at the site to indicate restricted access.

Fencing could achieve RAOs at some sites as a standalone technology and could be used in conjunction with other technologies to meet RAOs at other sites. This option is implementable. Fencing costs are relatively low. Fencing has been retained for further evaluation.

This response action includes security over the site during the period of institutional control, deed restrictions following the institutional control period, and monitoring of the condition of the tanks and the groundwater beneath them. The monitoring of the tanks would include periodic testing of their integrity. The groundwater monitoring and security would be implemented through INEEL-wide programs. Deed restrictions would be put in place as part of the closure operations to assure their inclusion on deeds in the event that the INEEL property changes ownership.

Institutional controls alone will not reduce contaminant toxicity, mobility, or volume and would be used only as an interim measure. Institutional controls are retained for further analysis since they are useful as a component of an alternative which also uses other technology(s).

10.3.3 Containment

Containment options for tank contents include capping the tank areas and installing hydraulic barriers. Each of these options are discussed in the following subsections.

10.3.3.1 Capping. A cap installed above the tank locations serves to deter inadvertent intrusion into the tanks or erosion of existing cover materials, and prevent percolation of precipitation which may mobilize contaminants in the event the tanks leak (i.e., contaminant mobilization in tank risers may occur if a leaking tank fills with precipitation).

A cap would require multiple layers, including a combination of basalt cobbles, gravel, and an armor rock surface. A layer of compacted clay would mitigate precipitation infiltration. Historically, clay has been considered a superior to a synthetic membrane for the impermeable barrier because of the uncertain design life for a synthetic membrane. However, in arid regions, clay caps may be subject to drying out and cracking.

The addition of the cap above the tanks may contribute to the collapse of the soil beneath the cap if the tank's structural integrity is diminished. Capping does not reduce the toxicity or volume of contaminants, but does provide some mitigation of their mobility due to precipitation infiltration. This technology does not eliminate horizontal or downward migration of contaminants from leakage of the tanks. The cost of the cap is moderate. Due to its limited effectiveness in preventing releases of contaminants from the tanks, capping was screened from further consideration.

10.3.3.2 Hydraulic Barriers. Horizontal and downward migration of contaminants can be mitigated by the installation of hydraulic barriers. Horizontal flow barriers include driven sheet piling, a deep soil mixing diaphragm wall, or a slurry wall. For long term consideration, the slurry wall is superior because it is constructed of natural materials and therefore is expected to have a longer design life. Vertical migration from tanks V-13 and V-14 is prevented by a concrete containment structure constructed beneath them. Vertical migration at other tanks can be mitigated by constructing a bottom barrier by the injection of grout in slanted grout holes strategically drilled to intersect beneath the tank; by jet grouting from holes drilled in the soil on either side of each tank; or by using a device referred to as a "sword" to lay a liner beneath the tanks from construction trenches which are parallel to the tanks and on either side.

While hydraulic barriers would mitigate the horizontal and vertical migration of contaminants, costs are high. In addition, the cell created around the tank by the barriers installed could fill with precipitation which may reach the ground surface. This "bathtubbing" phenomenon has occurred at shallow land burial sites with low permeability soils. In consideration of the potential lack of effectiveness and high cost, hydraulic barriers were screened from further consideration.

10.3.4 In Situ Treatment

Representative methods for in situ treatment of the tank contents include physical and chemical options. Because of the presence of organic materials in the sludges some of the methods considered may not be useable. The feasibility of some of the methods will be evaluated by treatability testing performed in conjunction with this FS.

10.3.4.1 *Physical Treatment.* The primary concern regarding the tank contents is the dose radiation rate associated with direct exposure. In the event that the tanks are exposed and/or breached, the release of the contents could impact human health and the environment through several different pathways. Potential risks could be mitigated by reducing contaminant mobility. Representative methods include stabilization and vitrification.

Stabilization could be accomplished by adding appropriate reagents to a tank and mixing with the contents using a remotely controlled mixing device. Reagents might include grout, sand, cement, clays, pozzolans, and/or polymers. The reagents used and suitable proportions would be selected during treatability testing. The mixture would fill the tank and therefore also reduce the risk of collapse. Implementability is uncertain because of the inability to develop a recipe to solidify the tank contents, and the required portable remotely controlled mixing device is still in the experimental stage. Toxicity of the stabilized waste would not be reduced, although the unit activity would be reduced, thereby reducing the direct radiation exposure. Also the contaminants would be less mobile in the event of a tank breach. The cost of in situ stabilization is relatively low. In situ solidification/stabilization was retained for further consideration.

In situ vitrification processes as previously described for treatment of soil are also considered for the tank contents. In situ vitrification vitrifies contaminated materials to create a monolithic stable, glass-like mass. Vitrification is achieved by applying large electrical currents to the material with graphite electrodes placed vertically in the material. The material mass bounded by the electrodes is heated to over 2000°F and melted. After cooling the resulting wasteform is a leach resistant glass-like form similar to obsidian.

The effectiveness of this option in meeting RAOs is estimated to be high if conducted properly. This option would mitigate the potential risks to human health and the environment by rendering the waste immobile thus preventing the potential for a release. Reduction in potential mobility via leaching and infiltration to groundwater, which is a primary benefit of vitrification, would be achieved. Toxicity of the radionuclides would not be reduced. In addition, the volume of contaminated materials would not be significantly reduced.

This technology is potentially effective at encapsulating radionuclide and inorganic contamination with the exception of mercury. With respect to mercury, volatilization is likely to occur. Volatile and semivolatile organic compounds were not above the detection limits in the TSF-26 tank content samples. PCBs were detected at levels below the treatment standards. This technology is implementable, but requires proximity to high-capacity electrical power lines. The cost of this technology is relatively high. The technology is retained for further evaluation.

10.3.4.2 *Chemical Leaching Treatment.* In situ chemical treatment can be used to reduce the mobility of the contaminants from the tank heel. Chemical leaching is accomplished by the introduction of solvents or chelating agents into the tank to selectively dissolve contaminants from the tank heel. Chemicals typically used include nitric acid, oxalic acid, or ethylenediaminetetraacetic acid (EDTA). The solution is then pumped from the tank, treated and disposed. Creation of a secondary waste stream adds to the complexity, particularly since the chemicals used may not be typical of those used elsewhere on INEEL, and therefore might require a separate treatment system. This increased complexity in addition to the small expected quantity of tank heel material would make the cost of chemical leaching high and the implementability difficult. Therefore chemical leaching was screened from further consideration.

10.3.5 Ex Situ Treatment

Ex situ treatment options are performed on tank contents after removal from in and around the tanks. Treatability studies have not been performed on the tank contents or the surrounding soils. Treatability test results can be used to further define the range of feasible process options.

The tank contents were sampled and analyzed to identify the radiological and hazardous constituents. Table 10-1, a summary of the analytical data, lists the maximum concentration for each measured constituent. The treatment standards for the components in the final waste form are also included.

10.3.5.1 Physical Treatment. Physical treatment options for tank liquids and heels include dewatering techniques, physical stabilization, vitrification, and encapsulation. Each of these are discussed in this section.

Certain tank heel removal methods use water as a transport medium. Subsequent ex situ treatment methods require material dewatering. The tank heel slurry is pumped from the tanks into temporary above ground storage tanks. The slurry is passed through a clarifier to thicken it, where the solids are dried further with a mechanical sludge press or a centrifuge. These are conventional water treatment process options and are considered implementable. The cost of dewatering is considered relatively low. Since dewatering is necessary for the implementation of subsequent process options, it is retained for further consideration.

Physical stabilization involves mixing the tank contents with materials such as clays or pozzolans. No chemical destruction of the hazardous components are performed. Treated material would be placed in a container suitable for disposal in an appropriately permitted disposal facility. Material proportions would be selected during treatability tests in order to meet the treatment requirements for the selected disposal facility. Mixing would be performed with a specialized portable device such as a high shear mixer or a pug mill. Appropriate controls for fugitive emissions and worker shielding would be used. Costs are moderate. This technique using portable mixing equipment is well developed and implementable. This process option is retained for further consideration.

Vitrification is an energy intensive process which requires special equipment. Vitrification would not offer any improvement over the effectiveness of physical stabilization to immobilize contaminants. Since treated waste volumes are reduced, direct radiation exposure from vitrified material would be greater than stabilized material. Vitrification costs would be high. Therefore this option is screened from further consideration.

Encapsulation involves enclosing tank contents in a specially constructed, high integrity container in which the material is placed. Tank contents would be pumped into these containers for long term storage. The use of high integrity containers is common in the nuclear industry; therefore, this process option is considered highly implementable. Encapsulation costs are moderate. Therefore this option is retained for further evaluation.

10.3.5.2 Chemical Treatment. Chemical treatment options for tank liquids and heels include chemical leaching and chemical stabilization. These two options are discussed in this section.

Chemical leaching involves the use of solvents or chelating agents to selectively dissolve contaminants of concern from the tank contents would concentrate, but not eliminate the contaminants.

Table 10-1. Treatment standards for chemical constituents of TSF-26 tanks.

Constituent	Max Level Detected (ppm) (Totals)	Characteristic Waste Treatment Standard (ppm)	Treatment Standard (ppm) Listed Waste	Specified Technology (if required)
V-13				
Arsenic	27.6	5.0 TCLP	—	—
Barium	102	100 TCLP	—	—
Cadmium	70.7	1.0 TCLP	—	—
Chromium	875	5.0 TCLP	—	—
Lead	594	5.0 TCLP	—	—
Mercury	79.7	0.20 TCLP	—	Retort or incineration if >260 ppm total Hg
Selenium	<4.7	5.7 TCLP	—	—
Silver	144	5.0 TCLP	—	—
		All TCLP organics are Total Analyses. Treatment residues must also pass 268.48 standards	F-Listed Organics must meet numerical standards (Totals Analysis), but are not required to meet 268.48 standards	—
Benzene	<220	10	10	—
Carbon Tetrachloride	<220	6	6	—
Chlordane	—	0.26	—	—
Chlorobenzene	—	—	—	—
Chloroform	<220	6	—	—
o-Cresol	—	5.6	5.6	—
m-Cresol	—	5.6	5.6	—
p-Cresol	—	5.6	5.6	—
Cresol	—	11.2	11.2	—
2,4-D	—	10	—	—
1,4-Dichlorobenzene	<170	6	—	—

Table 10-1. (continued).

Constituent	Max Level Detected (ppm) (Totals)	Characteristic Waste Treatment Standard (ppm)	Treatment Standard (ppm) Listed Waste	Specified Technology (if required)
V-13				
1,2-Dichloroethane	<220	6	—	—
1,1-Dichloroethylene	<220	6	—	—
2,4-Dinitrotoluene	<170	140	—	—
Endrin	—	0.13	—	—
Heptachlor (and epoxide)	—	0.066	—	—
Hexachlorobenzene	<170	10	—	—
Hexachlorobutadiene	<170	5.6	—	—
Hexachloroethane	<170	30	—	—
Lindane	—	0.066	—	—
Methoxychlor	—	0.18	—	—
Methyl ethyl ketone	—	36	36	—
Nitrobenzene	<170	14	14	—
Pentachlorophenol	<830	7.4	—	—
Pyridine	<170	16	16	—
Tetrachloroethylene	<220	6	6	—
Trichloroethylene	<220	6	6	—
2,4,5-Trichlorophenol	<830	7.4	—	—
2,4,6-Trichlorophenol	<170	7.4	—	—
2,4,5-TP (Silvex)	—	7.9	—	—
Vinyl Chloride	<220	6	—	—
pH	9.36	Neutralize and meet 268.48 standards, or Recover Organics, or Combust	—	—
Flashpoint	—	Deactivate	—	—
Reactive	—	Deactivate	—	—
Cyanides	—	590 ppm Total and 30 ppm Amenable	—	—

Table 10-1. (continued).

Constituent	Max Level Detected (ppm) (Totals)	Characteristic Waste Treatment Standard (ppm)	Treatment Standard (ppm) Listed Waste	Specified Technology (if required)
V-13				
Sulfides	—	500 ppm as Hydrogen Sulfide	—	—
Total Organic Carbon	17,100	—	—	>10% TOC—Recover Organics or Combust
Halogenated Organic Compounds	—	>1,000 HOCs—reduce to <1,000 ppm >10,000 HOCs—incinerate	—	—
Acetone	<220	—	160	—
n-Butyl Alcohol	—	—	2.6	—
Carbon Disulfide	<220	—	N/A	—
Cyclohexanone	—	—	N/A	—
1,2-Dichlorobenzene	<170	—	6	—
Ethyl Acetate	—	—	33	—
Ethyl Benzene	<220	—	10	—
Ethyl Ether	—	—	160	—
Isobutyl Alcohol	—	—	170	—
Methanol	—	—	N/A	—
Methylene Chloride	<220	—	30	—
Methyl Isobutyl Ketone	—	—	33	—
Toluene	<220	—	10	—
1,1,1-Trichloroethane	<220	—	6	—
1,1,2-Trichloroethane	—	—	6	—
1,1,2-Trichloro-1,2,2-Trifluoromethane	—	—	30	—
Trichloromonofluoro methane	—	—	30	—
Xylenes	<220	—	30	—

Table 10-1. (continued).

Constituent	Max Level Detected (ppm) (Totals)	Characteristic Waste Treatment Standard (ppm)	Treatment Standard (ppm) Listed Waste	Specified Technology (if required)
V-13				
Aroclor-1254	13 B	50–500 ppm—permitted landfill or chemical dehalogenation or incinerate	—	>500 ppm—incinerate
Aroclor 1260	11	50–500 ppm—permitted landfill or chemical dehalogenation or incinerate.	—	>500 ppm—incinerate

Chemical used often include, nitric acid, oxalic acid or EDTA. The solution would then be treated to re-solidify the material in a form suitable for disposal. Since this process option does not eliminate toxicity, it is not considered as an improvement over solidification. Its cost is relatively high. Because it involves an additional level of complexity, it is considered to be less implementable than physical stabilization. Therefore this option is screened from further consideration.

Chemical stabilization may be able to achieve the treatment criteria for a disposal facility without the volume increases associated with physical stabilization. Unlike physical stabilization alone, the addition of chemicals may enhance the structural stability of and lower the leachability or destroy contaminants from chemical sludges. Potential reagents include polymers, calcium or sodium silicates, and acid phosphates. The material specific reagents and their proportions would need to be determined by treatability testing. The chemicals would be mixed with the tank contents in a high shear mixer or similar device. Chemical stabilization is a well defined process option, and is considered implementable. Chemical stabilization costs are moderate, but higher than the cost of physical stabilization. Because of the potential for generating less volume for disposal, this process option is retained for further consideration.

10.3.6 Removal

Removal of the contents of the tank can be accomplished by remote or direct operations. Remote operation uses a device which is inserted through the existing tank manway to mobilize the heel and convey it to the surface. Direct operation involves excavating the soil covering the tank, cutting the tank open and removing its contents with conventional excavating equipment.

10.3.6.1 Remote Operation. Remote operation techniques include vacuuming or jetting and pumping. These two techniques are discussed in this section.

The use of vacuum devices has been widely used for decontamination of nuclear facilities. A vacuum line with lights and a television camera are attached to a telescoping robot arm or a crawler vehicle which is introduced to the tank through the manway. An operator on the surface guides the arm or vehicle to remove loose material from tank surfaces. The removed material is deposited in the vacuum cleaner chamber and is periodically emptied. In cases where long reaches are required, the vacuum cleaner chamber may be inside the tank to reduce the length of suction hose.

Material to be removed must be in a loose form. Compacted or cemented material may need to be prepared by mechanical scarification prior to vacuuming. This can be performed by specialized devices attached to the robot arm or crawler vehicle. Several passes of scarification and vacuuming equipment may be needed to achieve the required removal levels.

Vacuuming typically removes much of the material from tanks; however, residual contamination would likely remain in the tank. Vacuuming costs are high to mobilize the remotely operated equipment, and the difficulties of operation in a remote controlled environment. Since this represents a widely used decontamination and decommissioning technology the implementability of vacuuming is high. Vacuuming is retained for further consideration.

Logistic for jetting and pumping are similar to those used for vacuuming, except that water is used as the transport medium. A rotating cutter head is affixed to the end of a robot arm which is either introduced through the tank manway or attached to a remotely controlled vehicle. High pressure water is introduced through jet orifices in the cutter head to fragment the tank heel. Suction inlets around the perimeter of the cutter head pump the fragmented material to the surface, where it is treated and disposed.

Jetting and pumping costs are high to mobilize the remotely operated equipment, and the difficulties associated with operation in a remote controlled environment. The operation of this equipment involves the addition of a significant quantity of water to the tank. This may pose exposure concerns if the integrity of the tanks are marginal. Material removed must be dewatered prior to further treatment and disposal, adding complexity. While this process option is presently in the pilot development stage, implementation is feasible. If tank contents are solidified to the point where removal by mechanical scarification and vacuuming are not feasible, this technique may be practical. Jetting and pumping is retained for further consideration.

10.3.6.2 Direct Operation. Direct removal of the tank contents would be complicated by radiation exposure which precludes direct handling of the materials. Also, the potential for airborne releases of material would require that direct removal of tank contents be conducted in a contained environment. A temporary structure with a positive pressure ventilation system discharging through High Efficiency Particulate Air (HEPA) filters would be erected over the excavated tanks prior removal of their contents. The structure would include a traveling overhead crane. A cutting device would be operated from the crane to cut of the tank walls and expose the contents. The overhead crane and attached devices would be operated from within a shielded cab. Recovered materials would be placed in containers suitable for disposal or temporary storage prior to on-site or off-site treatment.

Due to the nature of the tank contents, efficient removal may be difficult with conventional equipment. Because of the cost of the temporary enclosure structure and indirect operational requirements, the cost of direct removal of tank contents is considered to be high. This technology has been successfully used in the site remediation industry. However, its implementability is moderate, considering the engineering controls required. Therefore, due to its moderate implementability and high cost, this process options is screened from further evaluation.

10.3.7 Disposal

Two disposal technologies, on-site and off-site, are considered. On-site refers to disposal at RWMC or at a proposed radionuclide-contaminated soil and debris landfill. Off-site refers to an appropriate disposal facility located offsite.

10.3.7.1 Disposal at RWMC. Disposal at the RWMC has been determined to be effective in protecting human health and the environment and meets the RAO's. Treatment of the removed material to meet waste acceptance criteria would be required prior to shipment to the RWMC. Costs are relatively high. This process option is retained for further evaluation.

10.3.7.2 Disposal at Proposed ER INEEL Soil Repository. Currently a landfill for low level radionuclide-contaminated soil and debris is proposed as part of the ER program at INEEL. However, the current status of this facility is uncertain. Costs for this facility would likely be much lower than current RWMC disposal fees. Although the timeframe associated with construction of the facility and its waste acceptance criteria are uncertain at this time, this option has been retained for further evaluation.

10.3.7.3 Off-Site Disposal. The Envirocare low-level radioactive waste disposal facility is located approximately 480 km (300 mi) from INEEL. The present isotopic inventory for the tank contents conforms to the requirements for Class B low-level radioactive waste under 10 Code of Federal Regulations (CFR) Section 61.55. Therefore, the tank contents would require treatment to meet the U.S. Nuclear Regulatory Commission's (NRC) requirements for a stable waste form prior to off-site disposal. The costs for off-site disposal are high. However, this process option has been retained for further consideration.

10.4 Technology Evaluation For TSF-09/-18 Tank Contents

This section discusses the identification and screening of processes for dealing with the contents of the USTs at OU 1-10 (i.e., TSF-09/-18 V1, V2, V3, and V9). This section addresses the fluid contents of the tanks as well as the solid heel which remains in the tank after free liquid is pumped out. Figure 10-4 graphically depicts the results of the screening process. The technologies and process options are discussed under the GRA's in the following subsections.

10.4.1 No Action

The No Action GRA does not involve remedial activities beyond site access controls and/or environmental monitoring currently conducted at INEEL as part of site-wide activities. Examples of these site access controls in the form of fences or caution tape which are designed to prevent exposure to contaminants in soil at the sites of concern. Environmental monitoring is included to enable identification of potential contaminant migration or other changes in site conditions that may warrant future remedial actions. The No Action GRA may not achieve RAOs established for OU 1-10, however, it is retained to serve as a baseline for evaluating remedial action measures.

Site access controls as described in Section 8.0 would be maintained. Environmental monitoring would be conducted through the existing INEEL site-wide program. Monitoring activities may consist of the collection and analysis of air, groundwater, soil, biota, and other media from the site as applicable. Air monitoring may include the use of high- and low-volume air samplers determine if fugitive metals escape

GRA	TECHNOLOGY/ PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
No Action	No Action	No additional activities beyond those currently conducted for INEEL site-wide requirements.	No action must be evaluated as a baseline alternative pursuant to the NCP.
Institutional Controls	Deed Restrictions	Deed restrictions on present and future land use; may include special building permit requirements.	Potentially applicable if tank contents remain on-site.
	Access Restrictions	Prevent physical access to the site using signs, fencing, physical structures (e.g., embankments), or security measures.	Potentially applicable if tank contents remain on-site.
Containment	Capping	Layers of soil and/or other materials are placed over tank locations to limit direct exposure and precipitation infiltration.	Low effectiveness in preventing potential releases from tanks. May contribute to structural failure of the tanks if integrity is diminished.
	Hydraulic Barriers	Installation of sheet piling, grout injection, or slurry wall to limit horizontal and vertical migration of contaminants	Uncertain effectiveness and high costs are associated.
In Situ Treatment	Physical Treatment	Stabilizing by adding ammendments, or thermal conversion of tank contents to obtain stable wasteform.	Potentially effective in reducing possible releases of tank contents to the environment. Thermal conversion is uncertain with metal tanks.
	Chemical Leaching Treatment	Addition of solvents, acids, chelating agents to selectively dissolve contaminants from tank materials.	Uncertain implementability and effectiveness for tank sites and secondary waste stream generation.
	Oxidation/ Reduction	Oxidizing and/or reducing reagents are mixed with waste to destroy toxic organics/cange oxidation state of heavy meatls.	Potentially effective; however, efficiency relies on through mixing which may be difficult since tanks do not have mixers.

Note: Double lines represent a technology or process option screened from further consideration

Figure 10-4. Technology screening summary for tank contents.

GRA	TECHNOLOGY/ PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
Ex Situ Treatment	Physical / Chemical Treatment	Neutralization, Oxidation/Reduction, Steam Reforming, Wet Air Oxidation, CEP, and Thermal Desorption options for liquid and solid tank contents.	All are not applicable to tank liquids and solids except Oxidation/Reduction. Oxidizing/reducing processes may be used as an ex-situ pre-treatment for Chemical Fixation/Stabilization.
	Fixation/Stabilization	Additives are used to immobilize hazardous and radioactive constituents and bind into solid form. Cementation, Amalgamation, and Encasulation.	Amalgamation may be considered to remove mercury from waste stream if cannot be adequately mobilized with pozzalonic materials.
	Vitrification	High temperature process used to immobilize hazardous and radioactive metals within a glass form.	Vitrification not considered a viable technology due to limited amount of solids in waste and associated cost.
	Incineration	Inceration of waste to destroy organic constituents in the waste	Potentially applicable for tank contents at OU 1-10.
	Separation	RO, ion-exchange, carbon adsorption, precipitation, centrifuge, drying, filtration, and distillation/ steam stripping options for liquid and solid tank contents	All are potentially applicable to tank liquids and solids except ion-exchange. Ion-exchange is not cost effective for the large volumes associated with the tank wastes.
	Evaporation	Process vaporizes the water from the waste, leaving the less volatile waste components in a concentrated solution.	Since VOC concentration in the tank waste is considered low, evaporation remains a viable treatment process.
	Biological	Bacteria are used to destroy organic constituents, used mostly on contaminated soils.	Due to experimental nature of the technology, biological treatment is not considered a viable technology.
Removal	Remote Operation	Uses vacuum devices or water/air jets and pumps to remove materials from tanks remotely.	Potentially applicable for tank contents at OU 1-10.
	Direct Operation	Removal of tank contents with conventional equipment such as clam-shell excavators, backhoes and dozers.	Uncertain effectiveness, low implementability, and high costs.
Disposal	On-Site at RWMC	Disposal at the INEEL RWMC.	Administrative difficulties due to discouragement toward disposal of environmental wastes at this facility.
	On-Site at Proposed ER INEEL Soil Repository	Disposal on-site at the proposed ER INEEL soil repository.	Effective in protecting human health and the environment, and in meeting RAOs.
	Off-Site At Permitted Low-Level Waste Disposal Facility	Disposal at off-site waste disposal facility such as Envirocare, WIPP, or Hanford, Barnwell, or Nevada Test Site.	Effective in protecting human health and the environment, and in meeting RAOs.

Note: Double lines represent a technology or process option screened from further consideration

Figure 10-4. (continued).

sites where contaminated surface soils exist. Groundwater monitoring may include monitoring contaminant migration in groundwater beneath the site.

Actions taken to reduce the potential for exposure are not included. Under present conditions, the tanks and the soil cover over the tanks are intact. Therefore, since the 3.05 m (10 ft) of soil cover provides sufficient shielding the No Action GRA may be protective of human health and the environment. If no further maintenance is performed, the tanks may fail or be breached by accidental intrusion in the future. If the tanks were breached, the risk to human health may be significant.

10.4.2 Institutional Controls

Institutional controls include actions taken by the responsible authorities to minimize potential danger to human health and the environment. Institutional controls are ongoing actions that can be maintained only for as long as the responsible authority is in control of the site. Based on the *INEL Comprehensive Facility and Land Use Plan* (DOE-ID 1996) institutional controls will be maintained for a minimum of 100 years following site closure. To remain consistent with the BRA, the 100-year institutional control period is assumed to begin in 1998. Representative types of institutional control include deed restrictions and land-use restrictions.

10.4.2.1 Deed Restrictions. A deed restriction is a legally binding deed notice that limits the available use of and activities which can be performed at a given site. These restrictions prevent the completion of exposure pathways that would result in an unacceptable risk to human health. Zoning regulations are one form of deed restrictions and are the primary vehicle for specifying appropriate land use.

Deed restrictions could possibly achieve RAOs at some sites as a standalone technology and could be used in conjunction with other technologies to meet RAOs at other sites. This option is implementable, and deed restriction costs are relatively low. Deed restrictions have been retained for further evaluation.

10.4.2.2 Access Restrictions. Fencing is a representative type of access restriction. Fencing involves enclosing individual or contiguous areas within a fence with a locking gate. This institutional control reduces risks to human health by limiting exposure to contaminants in soil. It is a viable technology for contamination that is not likely to become airborne. Signage is typically placed at the site to indicate restricted access.

Fencing could achieve RAOs at some sites as a standalone technology and could be used in conjunction with other technologies to meet RAOs at other sites. This option is implementable. Fencing costs are relatively low. Fencing has been retained for further evaluation.

This response action includes security over the site during the period of institutional control, deed restrictions following the institutional control period, and monitoring of the condition of the tanks and the groundwater beneath them. The monitoring of the tanks would include periodic testing of their integrity. The groundwater monitoring and security would be implemented through INEEL-wide programs. Deed restrictions would be put in place as part of the closure operations to assure their inclusion on deeds in the event that the INEEL property changes ownership.

Institutional controls alone will not reduce contaminant toxicity, mobility, or volume and would be used only as an interim measure. Institutional controls are retained for further analysis since they are useful as a component of an alternative which also uses other technology(s).

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Containment options for tank contents include capping the tank areas and installing hydraulic barriers. Each of these options are discussed in the following subsections.

10.4.3.1 Capping. A cap installed above the tank locations serves to deter inadvertent intrusion into the tanks or erosion of existing cover materials, and prevent percolation of precipitation which may mobilize contaminants in the event the tanks leak (i.e., contaminant mobilization in tank risers may occur if a leaking tank fills with precipitation).

A cap would require multiple layers, including a combination of basalt cobbles, gravel, and an armor rock surface. A layer of compacted clay would mitigate precipitation infiltration. Historically, clay has been considered a superior to a synthetic membrane for the impermeable barrier because of the uncertain design life for a synthetic membrane. However, in arid regions, clay caps may be subject to drying out and cracking.

The addition of the cap above the tanks may contribute to the collapse of the soil beneath the cap if the tank's structural integrity is diminished. Capping does not reduce the toxicity or volume of contaminants, but does provide some mitigation of their mobility due to precipitation infiltration. This technology does not eliminate horizontal or downward migration of contaminants from leakage of the tanks. The cost of the cap is moderate. Due to its limited effectiveness in preventing releases of contaminants from the tanks, capping was screened from further consideration.

10.4.3.2 Hydraulic Barriers. Horizontal and downward migration of contaminants can be mitigated by the installation of hydraulic barriers. Horizontal flow barriers include driven sheet piling, a deep soil mixing diaphragm wall, or a slurry wall. For long term consideration, the slurry wall is superior because it is constructed of natural materials and therefore is expected to have a longer design life. Vertical migration from tanks V-13 and V-14 is prevented by a concrete containment structure constructed beneath them. Vertical migration at other tanks can be mitigated by constructing a bottom barrier by the injection of grout in slanted grout holes strategically drilled to intersect beneath the tank; by jet grouting from holes drilled in the soil on either side of each tank; or by using a device referred to as a "sword" to lay a liner beneath the tanks from construction trenches which are parallel to the tanks and on either side.

While hydraulic barriers would mitigate the horizontal and vertical migration of contaminants, costs are high. In addition, the cell created around the tank by the barriers installed could fill with precipitation which may reach the ground surface. This "bathtubbing" phenomenon has occurred at shallow land burial sites with low permeability soils. In consideration of the potential lack of effectiveness and high cost, hydraulic barriers were screened from further consideration.

10.4.4 In Situ Treatment

Representative methods for in situ treatment of the tank contents include physical and chemical options. Because of the presence of organic materials in the sludges some of the methods considered may not be useable. The feasibility of some of the methods will be evaluated by treatability testing performed in conjunction with this FS; however, because treatment efficiency relies on thorough mixing of the tank contents, viability of in situ treatment is questionable.

10.4.4.1 Physical Treatment. The primary concern regarding the tank contents is the dose radiation rate associated with direct exposure. In the event that the tanks are exposed and/or breached, the release of the contents could impact human health and the environment through several different pathways. Potential risks could be mitigated by reducing contaminant mobility. Representative methods include stabilization and vitrification.

Stabilization could be accomplished by pumping the tank contents to the surface and then adding appropriate reagents mixing the contents and pumping the contents back into the tanks. Reagents might include grout, sand, cement, clays, pozzolans, and/or polymers. The reagents used and suitable proportions would be selected during treatability testing. The mixture would fill the tank and therefore also reduce the risk of collapse. Implementability is uncertain because of the inability to develop a recipe to solidify the tank contents, and the required portable remotely controlled mixing device is still in the experimental stage. Toxicity of the stabilized waste would not be reduced, although the unit activity would be reduced, thereby reducing the direct radiation exposure. Also the contaminants would be less mobile in the event of a tank breach. The cost of in situ stabilization is relatively low. In situ solidification/stabilization was retained for further consideration.

In situ vitrification processes as previously described for treatment of the TSF-26 tank contents is also considered for the TSF-09/-18 tank contents. Vitrification is achieved by applying large electrical currents to the material with graphite electrodes placed vertically in the material. The material mass bounded by the electrodes is heated to over 2000°F and melted. After cooling the resulting wasteform is a leach resistant glass-like form similar to obsidian.

The effectiveness of this option in meeting RAOs is estimated to be high if conducted properly. This option would mitigate the potential risks to human health and the environment by rendering the waste immobile thus preventing the potential for a release. Reduction in potential mobility via leaching and infiltration to groundwater, which is a primary benefit of vitrification, would be achieved. Toxicity of the radionuclides would not be reduced. In addition, the volume of contaminated materials would not be significantly reduced.

This technology is potentially effective at encapsulating inorganic contamination with the exception of mercury. With respect to mercury and the other volatile and semivolatile compounds detected in the tank waste samples, volatilization is likely to occur. PCBs were also detected in the tank waste samples. This technology is implementable, but requires proximity to high-capacity electrical power lines. The cost of this technology is relatively high. The technology is retained for further evaluation.

10.4.4.2 Chemical Treatment. In situ chemical treatment can be used to reduce the mobility of the contaminants from the tank heel. Chemical leaching is accomplished by the introduction of solvents or chelating agents into the tank to selectively dissolve contaminants from the tank heel. Chemicals typically used include nitric acid, oxalic acid, or EDTA. The solution is then pumped from the tank, treated and disposed. Creation of a secondary waste stream adds to the complexity, particularly since the chemicals used may not be typical of those used elsewhere on INEEL, and therefore might require a separate treatment system. This increased complexity in addition to the small expected quantity of tank heel material would make the cost of chemical leaching high and the implementability difficult. Therefore chemical leaching was screened from further consideration.

10.4.4.3 Oxidation/reduction Oxidation/reduction processes can also be considered as an in situ treatment for the tank contents. Oxidizing and/or reducing reagents are mixed with the waste to destroy toxic organics or to change the oxidation state of heavy metals. However, its efficiency relies on thorough mixing of the chemicals with the waste which may be difficult to achieve since the tanks are not equipped with mixers. Also, it is not known what impact the reagents would have on the sludge in the tank. Therefore in-situ oxidation/reduction is not considered to be a viable treatment process.

10.4.5 Ex situ Treatment

Ex situ treatment options are performed on the tank contents after removal from in and ,if applicable, around the tanks. Treatability studies have not been performed on the tank contents or the surrounding soils. Treatability test results can be used to further define the range of feasible process options.

The waste liquids and solids in TSF-09/18, referred to as "tanks", were sampled and analyzed to identify the radiological and hazardous constituents Table 10-2, a summary of the analytical data, lists the maximum concentration for each measured constituent. The data indicates there are low concentrations of RCRA regulated components and polychlorinated biphenyls (PCBs) in the V-tanks. The treatment standards for the components in the final waste form are also included.

The primary problematic radioactive component is Cs-137 in the V-tanks. Although the liquid activity is only 4 mrem/hr, the measured activity for the sludges are above the limit of 200 mrem/hr for contact handled waste. This implies that gamma shielding will be necessary when removing, transferring and treating the tank waste. Due to the diverse physical and chemical properties of the waste contaminants, individually, few waste treatment technologies will adequately treat the tank waste by themselves. Successful waste treatment may require a combination of two or more technologies.

The waste treatment technologies considered for the tank wastes include the following:

- Physical/Chemical Treatment
- Chemical Fixation and Stabilization
- Vitrification
- Incineration
- Separation
- Evaporation
- Biological.

10.4.5.1 Physical/Chemical Treatment. Treatment processes in this category include:

- Neutralization
- Oxidation/Reduction
- Steam Reforming
- Wet Air Oxidation

Table 10-2. Treatment standards for chemical constituents of TSF-09/18 tanks.

Constituent	Max Level Detected (ppm) (Totals)				Characteristic Waste Treatment Standard (ppm)	Treatment Standard (ppm) Listed Waste	Specified Technology (if required)
	V1	V2	V3	V9			
Arsenic	18.8	18.5	19	<0.4	5.0 TCLP	—	—
Barium	385	187	184	374	100 TCLP	—	—
Cadmium	170	108	81.4	27	1.0 TCLP	—	—
Chromium	1,740	1,680	947	1,040	5.0 TCLP	—	—
Lead	1,640	1,550	1,370	560	5.0 TCLP	—	—
Mercury	1,590	612	1,390	2,080	0.20 TCLP	—	Retort or incineration if >260 ppm total Hg
Selenium	3	7.8	2.7	4	5.7 TCLP	—	—
Silver	446	118	198	651	5.0 TCLP	—	—
					All TCLP organics are Total Analyses. Treatment residues must also pass 268.48 standards	F-Listed Organics must meet numerical standards (Totals Analysis), but are not required to meet 268.48 standards	—
Benzene	<10	<10	<10	<250	10	10	—
Carbon Tetrachloride	<10	<10	<10	<120	6	6	—
Chlordane	—	—	—	—	0.26	—	—
Chlorobenzene	<10	<10	—	<120	—	—	—
Chloroform	<10	<10	<10	<120	6	—	—

Table 10-2. (continued).

Constituent	Max Level Detected (ppm) (Totals)				Characteristic Waste Treatment Standard (ppm)	Treatment Standard (ppm) Listed Waste	Specified Technology (if required)
	V1	V2	V3	V9			
o-Cresol	<270	<230	<270	490	5.6	5.6	—
m-Cresol	—	—	—	—	5.6	5.6	—
p-Cresol	<270	<230	<270	260	5.6	5.6	—
Cresol	—	—	—	—	11.2	11.2	—
2,4-D	—	—	—	—	10	—	—
1,4-Dichlorobenzene	<270	<230	<270	90	6	—	—
1,2-Dichloroethane	<10	<10	<10	—	6	—	—
1,1-Dichloroethylene	—	—	—	—	6	—	—
2,4-Dinitrotoluene	<270	<230	<270	<150	140	—	—
Endrin	—	—	—	—	0.13	—	—
Heptachlor (and epoxide)	—	—	—	—	0.066	—	—
Hexachlorobenzene	—	—	—	—	10	—	—
Hexachlorobutadiene	—	—	—	<150	5.6	—	—
Hexachloroethane	<270	<180	<270	<150	30	—	—
Lindane	—	—	—	—	0.066	—	—
Methoxychlor	—	—	—	—	0.18	—	—
Methyl ethyl ketone	<10	<10	<10	<750	36	36	—
Nitrobenzene	<270	<230	<270	<150	14	14	—

Table 10-2. (continued).

Constituent	Max Level Detected (ppm) (Totals)				Characteristic Waste Treatment Standard (ppm)	Treatment Standard (ppm) Listed Waste	Specified Technology (if required)
	V1	V2	V3	V9			
Pentachlorophenol	<1,400	<1,100	<1,300	<770	7.4	—	—
Pyridine	<270	<230	<270	<150	16	16	—
Tetrachloroethylene	1,800	510	480	<460	6	6	—
Trichloroethylene	230	<0.68	<0.63	22,000	6	6	—
2,4,5-Trichlorophenol	<1,400	<1,100	<1,300	<770	7.4	—	—
2,4,6-Trichlorophenol	<270	<180	<270	<150	7.4	—	—
2,4,5-TP (Silvex)	—	0.02	0.01	—	7.9	—	—
Vinyl Chloride	<10	<10	<10	420	6	—	—
pH	8.14	7.91	7.86	7.79	Neutralize and meet 268.48 standards, or Recover Organics, or Combust	—	—
Flashpoint	—	—	—	—	Deactivate	—	—
Reactive	—	—	—	—	Deactivate	—	—
Cyanides	—	—	—	—	590 ppm Total and 30 ppm Amenable	—	—
Sulfides	—	—	—	—	500 ppm as Hydrogen Sulfide	—	—

Table 10-2. (continued).

Constituent	Max Level Detected (ppm) (Totals)				Characteristic Waste Treatment Standard (ppm)	Treatment Standard (ppm) Listed Waste	Specified Technology (if required)
	V1	V2	V3	V9			
Total Organic Carbon	65.9	—	—	10,023	—	—	>10% TOC— Recover Organics or Combust
Halogenated Organic Compounds	—	—	—	—	>1,000 HOCs—reduce to <1,000 ppm >10,000 HOCs—incinerate	—	—
Acetone	<10	<10	<10	<1,400	—	160	—
n-Butyl Alcohol	—	—	—	—	—	2.6	—
Carbon Disulfide	<10	<10	<10	—	—	N/A	—
Cyclohexanone	—	—	—	—	—	N/A	—
1,2-Dichlorobenzene	<270	<180	50	350	—	6	—
Ethyl Acetate	—	—	—	—	—	33	—
Ethyl Benzene	—	—	—	<120	—	10	—
Ethyl Ether	—	—	—	—	—	160	—
Isobutyl Alcohol	—	—	—	—	—	170	—
Methanol	—	—	—	—	—	N/A	—
Methylene Chloride	<10	<10	<10	<250	—	30	—
Methyl Isobutyl Ketone	<10	<10	—	—	—	33	—
Toluene	<10	<10	<10	<250	—	10	—

Table 10-2. (continued).

Constituent	Max Level Detected (ppm) (Totals)				Characteristic Waste Treatment Standard (ppm)	Treatment Standard (ppm) Listed Waste	Specified Technology (if required)
	V1	V2	V3	V9			
1,1,1-Trichloroethane	<10	<10	<10	1,800	—	6	—
1,1,2-Trichloroethane	<10	<10	<10	<120	—	6	—
1,1,2-Trichloro-1,2,2-Trifluoromethane	—	—	—	—	—	30	—
Trichloromonofluoro methane	—	—	—	—	—	30	—
Xylenes	<10	<10	<10	<120	—	30	—
Aroclor 1260	660	260	400	310	50–500 ppm— permitted landfill or chemical dehalogenation or incinerate.	—	>500 ppm— incinerate

- Catalytic Extraction Process (CEP)

- Thermal Desorption.

Neutralization is used to treat corrosive and/or reactive wastes. Since the tank waste pH is in the range of 7 to 8, neutralization is not required and removed from further consideration.

Oxidizing and/or reducing reagents are mixed with the waste to destroy toxic organics or to change the oxidation state of heavy metals. This technology can be applied ex-situ. If TCLP tests show that chromium or other heavy metals are difficult to stabilize, it may be necessary to use this technology as an ex-situ pretreatment for Chemical Fixation and Stabilization. Therefore this technology remains as a possible treatment process.

Steam reforming is designed for waste containing organic material. It uses superheated steam to reduce the waste before it is burned in a special reactor without oxygen. This is not considered to be a feasible technology for the tank waste since the waste does not contain large quantities of organic material and would not be cost effective.

Wet air oxidation destroys organic wastes using an oxidant in water at high temperatures and pressures. As a possible treatment for PCBs, a supplier of the technology was contacted for information relating to PCB destruction. The vendor is unaware of anyone using this technology to treat PCBs. Bench-scale studies conducted in the 1980's indicate a 50 to 90% PCB destruction using Wet Air Oxidation. Due to the limited amount of PCB destruction information and the treatment's complexity/cost, Wet Air Oxidation is removed from further consideration.

Catalytic Extraction Process uses molten metal as a catalyst and solvent to destroy mixed wastes containing organics and heavy metals. Since the tank waste does not contain large quantities of either material, CEP is not considered to be a cost effective technology.

Thermal desorption uses indirect heating to volatilize the organics. If operated in a batch mode, the process can be operated in a vacuum and at relatively low temperatures. If the tank waste were to be treated with this process, the volatilized components would need to be treated or collected as a waste product. Vapor treatment could include catalytic oxidation or incineration. This low temperature process would not volatilize PCBs. It is not considered to be an acceptable tank waste treatment method.

10.4.5.2 Physical Treatment.

10.4.5.2.1 Chemical Fixation and Stabilization—Treatment processes in chemical fixation and stabilization category include:

- Portland Cement Systems

- Amalgamation

- Encapsulation.

Chemical fixation and stabilization technologies immobilize the waste's radioactive and hazardous constituents by using additives which bind them into a solid waste form.

Cement solidification/stabilization processes are commonly used to treat aqueous liquids similar to the tank wastes and the treatment can be performed in situ or ex situ. Ex situ treatment with cement and/or fly ash additives is retained as a possible treatment process. This technology has been used to treat PCB waste. However, it will be difficult to locate a mixed waste disposal facility which can accept PCBs without reducing their concentration prior to solidification/stabilization treatment. In addition, if this technology is used to treat PCB waste, a variance to the PCB treatment standards will be required.

Amalgamation is used to remove mercury from liquid or gas waste streams. It may be necessary to use this technology if the metal, as determined bench-scale tests, can not be adequately immobilized with pozzalonic materials.

Encapsulation encases the waste in a matrix of polymer, plastics or asphalt. The treatment technology is used to immobilize solids containing hazardous metals. This technology could be used if the solids are removed from the tank waste, dried and mixed with the formulated matrix. The development for this treatment alternative is considered to be too costly for the amount of solids in the waste. In addition, the long term stability of polymers and plastic in contact with radioactive waste is unknown. Encapsulation is not considered to be a viable treatment for the tank waste.

10.4.5.2.2 Vitrification—Vitrification is a high temperature process designed to immobilize hazardous and radioactive metals within a glass form. This technology does not treat aqueous waste. It could be used to treat the solids if they are removed from the tank liquid waste and dried. Ex situ treatment by vitrification is considered to be a viable technology due to the limited amount of solids in the waste and associated cost to treat them.

The U.S. Department of Energy (DOE) plans to permit and construct the Advanced Mixed Waste Treatment Facility (AMWTF). This plant will be designed to treat the alpha and transuranic (TRU) mixed waste located at the RWMC. The AMWTF may employ glass melter technology to treat wastes. The RWMC wastes are solids which are conducive to treatment in a glass melted. At this time, the ability and availability of the AMWTF to treat the tank aqueous waste is unknown.

10.4.5.2.3 Incineration—Incineration is the treatment standard for waste containing PCBs. The technology is commonly used to destroy the organic constituents in the waste and is a viable technology for the tank wastes. Although incineration does not destroy the radioactive contaminants, it will greatly reduce the waste volume since the water will be evaporated and treated in the associated off-gas treatment system. The resulting ash and off-gas treatment residues may need to be treated with an immobilization reagent prior to final disposal. The technology is retained for further consideration.

The waste acceptance criteria for the K-25 TSCA incinerator located at Oak Ridge National Laboratory was reviewed with regard to the tank waste characteristics. It appears that the tank waste could be treated at the incinerator. Currently there is no charge for the treatment other than shipping costs to the site and arrangements for treatment must be coordinated through the DOE; however (at present) treatment of out-of-state waste is prohibited.

Currently the treatment residues associated with the incinerator and off-gas treatment system are being sent to Envirocare for disposal. If disposal becomes an issue, the residues will be sent back to the generator. Since the incinerator conducts waste feed blending for efficient operation, it is very probable that the residues will have additional waste codes and/or radioisotopes associated with the residues.

The plasma hearth process which is currently being constructed to remediate Pit-9 at the RWMC could be used to treat the tank waste. Currently, the Pit-9 facility is not permitted to treat RCRA or Toxic Substances Control Act (TSCA) wastes. Plans to permit the treatment process exist but it is uncertain when the facility will be available for treating the tank waste.

10.4.5.2.4 Separation—Treatment processes in this category include:

- Reverse Osmosis
- Ion-exchange
- Carbon Absorption
- Precipitation
- Centrifuge
- Drying
- Filtration
- Distillation/Steam Stripping.

If the solids are removed from the tank waste, the liquids could be processed through a semi-permeable membrane to remove dissolved contaminants. Reverse osmosis (RO) can significantly reduce the amount of liquid requiring treatment. It is considered a viable treatment option.

Ion exchange technology could be used to remove most of the Cs-137 and Co-60 from the tank waste. However, the resulting waste product would still contain other radioactive components such as tritium and Sr-90. The technology is not considered to be cost effective for the tank waste since they are designed to treat large volumes of wastewater and would produce a secondary waste product requiring further treatment for disposal.

Carbon adsorption is a technology for removing relatively dilute concentrations of contaminants from liquid or gas streams. Since the organic and inorganic concentrations in the tank waste are very low, this technology is considered to be workable if the solids are removed from the liquids prior to treatment. The disadvantage for this process is that the spent carbon would need to be treated prior to disposal since it would be a mixed waste. Carbon adsorption is retained as a possible treatment process.

Chemical precipitation is used to change the solubility of a dissolved contaminant by either changing the contaminant's form to a less soluble one or changing the solvent's chemistry to decrease the contaminant's solubility. Hydroxide precipitation is effective for removing arsenic, cadmium, Cr^{+3}, iron, manganese, nickel, lead, and zinc and certain radioactive species from aqueous solutions. The precipitate is filtered from the treated waste stream and requires additional treatment such as immobilization prior to disposal. This technology is considered to be usable if the solids are removed from the liquids prior to treatment.

Centrifuges are used to separate a two phase waste stream similar to the tank waste. Centrifuges are designed to remove solids which have densities similar to the solvent which is applicable to the tank waste. Therefore, this technology is retained as a candidate technology for removing the solids from the tank waste.

Thermal drying is used to remove water from solids. This unit operation could be used to dry the solids should they be removed from the tank waste or the filter cake should precipitation be used. However, in either case, the resulting solids would require additional treatment such as immobilization prior to disposal. The technology is not considered to be effective for treating the tank waste.

Filtration is common technology used to separate solids from liquids. The type of filter used depends upon the waste quantity and particle size of the solids processed. Filtration is considered to be a potential treatment process for the tank waste. The technology could be used for removing the solids from the tank waste and/or those resulting from chemical precipitation. The quantity of waste requiring filtration does not justify a continuous operation. It is anticipated that a batch operated, disposable cartridge filter would be used.

Distillation or steam stripping is used to remove volatile organics from aqueous waste streams. Since the volatile organic compounds (VOC) concentrations in the tank wastes are very low, distillation is not considered to be economically feasible. However, stream stripping may be an acceptable treatment option.

10.4.5.2.5 Evaporation—Evaporation can be used to reduce the volume of aqueous wastes. The process vaporizes the water from the waste while the less volatile waste components remain in a concentrated solution. This technology is feasible if VOCs with lower vapor pressures (i.e., boiling point temperatures) are not present in the waste. If the waste does contain low boiling VOCs, then additional treatment of the vaporized organics is required. Depending upon the relative concentrations of the organics, this treatment could be as complex as oxidation or as simple as carbon adsorption. Since the VOC concentration in the tank waste is considered low, evaporation remains a viable treatment process.

The Process Equipment Waste system (PEW), located at the Idaho Chemical Processing Plan (ICPP), is a RCRA permitted evaporation process used to reduce the volume of aqueous waste streams. The chemical acceptance criteria for the PEW was reviewed for possible treatment of the tank waste. Although the total organic carbon (TOC) for the waste is below the acceptance limit, there are several constituents which exceed the constraints stated in the acceptance criteria. These include arsenic, barium, cadmium, chromium, lead, mercury, and PCBs. The limit for PCBs is 50 mg/l. Removing the solids from the tank waste could reduce the PCB concentration below 50 mg/l. However, additional treatment for the RCRA regulated metals would be associated with the V-tanks before the waste could be sent to the PEW. Since treatment for all the metals would require several unit operations (i.e., precipitation, amalgamation, and possibly oxidation/reduction), the option for sending treated tank waste to the PEW is not retained for further consideration due to treatment complexity and cost.

10.4.5.2.6 Biological—Biological treatment includes using bacteria to destroy organic constituents. The technology is used mostly on contaminated soils. Inquiries were made concerning the possibility of using this technology to treat the PCBs in situ. It appears that this technology would be an experimental treatment method since no one seems to have successfully treated PCBs in a liquid waste media. In order for the bacteria to work, they must have the right living conditions which would require adding nutrients and perhaps heat to the tank waste. Gentle agitation would be required to commingle the bacteria with the PCBs since the PCBs are located in the solid sludge. Due to the experimental nature of the technology, this is not considered to be a feasible treatment method.

10.4.6 Removal

Removal of the contents of the tank can be accomplished by remote or direct operations. Remote operation uses a device which is inserted through the existing tank manway to mobilize the heel and convey it to the surface. Direct operation involves excavating the soil covering the tank, cutting the tank open and removing its contents with conventional excavating equipment.

10.4.6.1 Remote Operation. Remote operation techniques include vacuuming or jetting and pumping. These two techniques are discussed in this section.

The use of vacuum devices has been widely used for decontamination of nuclear facilities. A vacuum line with lights and a television camera are attached to a telescoping robot arm or a crawler vehicle which is introduced to the tank through the manway. An operator on the surface guides the arm or vehicle to remove loose material from tank surfaces. The removed material is deposited in the vacuum cleaner chamber and is periodically emptied. In cases where long reaches are required, the vacuum cleaner chamber may be inside the tank to reduce the length of suction hose.

Material to be removed must be in a loose form. Compacted or cemented material may need to be prepared by mechanical scarification prior to vacuuming. This can be performed by specialized devices attached to the robot arm or crawler vehicle. Several passes of scarification and vacuuming equipment may be needed to achieve the required removal levels.

Vacuuming typically removes much of the material from tanks; however, residual contamination would likely remain in the tank. Vacuuming costs are high to mobilize the remotely operated equipment, and the difficulties of operation in a remote controlled environment. Since this represents a widely used decontamination and decommissioning (D&D) technology the implementability of vacuuming is high. Vacuuming is retained for further consideration.

Logistic for jetting and pumping are similar to those used for vacuuming, except that water is used as the transport medium. A rotating cutter head is affixed to the end of a robot arm which is either introduced through the tank manway or attached to a remotely controlled vehicle. High pressure water is introduced through jet orifices in the cutter head to fragment the tank heel. Suction inlets around the perimeter of the cutter head pump the fragmented material to the surface, where it is treated and disposed.

Jetting and pumping costs are high to mobilize the remotely operated equipment, and the difficulties associated with operation in a remote controlled environment. The operation of this equipment involves the addition of a significant quantity of water to the tank. This may pose exposure concerns if the integrity of the tanks are marginal. Material removed must be dewatered prior to further treatment and disposal, adding complexity. While this process option is presently in the pilot development stage, implementation is feasible. If tank contents are solidified to the point where removal by mechanical scarification and vacuuming are not feasible, this technique may be practical. Jetting and pumping is retained for further consideration.

10.4.6.2 Direct Operation. Direct removal of the tank contents would be complicated by radiation exposure which precludes direct handling of the materials. Also, the potential for airborne releases of material would require that direct removal of tank contents be conducted in a contained environment. A temporary structure with a positive pressure ventilation system discharging through HEPA filters would be erected over the excavated tanks prior removal of their contents. The structure would include a traveling overhead crane. A cutting device would be operated from the crane to cut of the tank walls and expose the contents. The overhead crane and attached devices would be operated from within a shielded cab. Recovered materials would be placed in containers suitable for disposal or temporary storage prior to on-site or off-site treatment.

Due to the nature of the tank contents, efficient removal may be difficult with conventional equipment. Because of the cost of the temporary enclosure structure and indirect operational requirements, the cost of direct removal of tank contents is considered to be high. This technology has been successfully used in the site remediation industry. However, its implementability is moderate, considering the engineering controls required. Therefore, due to its moderate implementability and high cost, this process options is screened from further evaluation.

10.4.7 Disposal

Two disposal technologies, on-site and off-site, are considered. On-site refers to disposal at RWMC or at a proposed INEEL-ER soil repository. Off-site refers to an appropriate disposal facility located offsite.

10.4.7.1 Disposal at RWMC. The low level waste acceptance criteria for INEL's Waste Experimental Reduction Facility (WERF) and the RWMC, as described in DOE/ID-10381, Revision 5, was reviewed for their ability to receive the tank waste. The following is a list of criteria which are problematic for using the RWMC as the disposal facility for the tank waste:

- Wastes contaminated with transuranic isotopes having activities less than 100 nCi/g but more than 10 nCi/g are excluded from disposal at the RWMC. In order to permanently dispose of the waste at the RWMC, the treatment process would need to concentrate the TRU activity.

- Waste with PCB concentrations greater than 50 ppm are excluded from disposal at the RWMC. The PCB limit for the WERF facility is 5 ppm. If the PCB concentration in the V-Tank waste is not reduced, the treated waste product can not be disposed at the RWMC. PCB concentrations in the PM2A tank waste are less than 50 ppm.

It should be noted that the waste can be temporarily stored at the RWMC in accordance to its permit.

Disposal at the RWMC has been determined to be effective in protecting human health and the environment and meets the RAO's. Costs are relatively high. This process option is retained for further evaluation since there are treatment alternatives being considered which can produce a waste product acceptable to the RWMC.

10.4.7.2 Disposal at Proposed ER INEEL Soil Repository. Currently a landfill for low level radionuclide-contaminated soil and debris is proposed as part of the ER program at INEEL. However, the current status of this facility is uncertain. Costs for this facility would likely be much lower than current RWMC disposal fees. Although the timeframe associated with construction of the facility and its waste acceptance criteria are uncertain at this time, this option has been retained for further evaluation.

10.4.7.3 Off-Site Disposal. The waste acceptance criteria for several mixed waste disposal facilities were reviewed for their suitability to accept the tank waste. These facilities include the:

- Waste Isolation Pilot Plant (WIPP)
- Hanford's Environmental Restoration Disposal Facility (ERDF)
- Envirocare
- Barnwell Waste Management Facility
- Nevada Test Site.

The costs for off-site disposal are high. However, this process option has been retained for further consideration. Additionally, hazardous waste disposal facilities were not included in the analysis because free release limits for radioactive waste, treated or untreated, are nonexistent making it unfeasible to ship mixed waste to a RCRA permitted disposal facility.

10.4.7.3.1 Waste Isolation Pilot Plant—WIPP's waste acceptance criteria, as described in document DOE/WIPP-069, Revision 5, states that the lower limit for contact or remote handled TRU waste is 100 nanocuries per gram (nCi/g) of TRU radionuclides. Radiological analysis indicates that the TRU activity of the waste in the tanks is below this limit. When using the maximum value for each measured TRU radionuclide in the V-Tank waste, the TRU activity in the waste solids is in the range of 30 to 80 nCi/g and averages 40 nCi/g in the liquid If a waste volume reduction process such as evaporation is used, it is feasible that a concentrate can be produced which has a specific activity of more than 100 nCi/g TRU radionuclides. Therefore, depending upon the treatment process, WIPP is a possible depository for the final waste product.

10.4.7.3.2 Hanford's Environmental Restoration Disposal Facility (ERDF)—A review of ERDF's waste acceptance criteria was performed. This criteria is described in document BHI-00139 Revision 0. The following is a description of the waste acceptance criteria which are considered to be problematic for accepting the tank waste.

- "Solidified organic liquids containing 500 ppm or greater PCBs will not be accepted for disposal." This means that the tank waste would need to be treated for PCBs before it is disposed at ERDF.
- Currently ERDF does not accept any waste outside of the Hanford reservation.

The ERDF facility is retained as a feasible location for the final waste disposal since there are PCB treatment processes under consideration which could produce an acceptable waste product.

10.4.7.3.3 Envirocare—A review of Envirocare's radioactive material license summary, indicates that his facility can accept mixed waste. However, discussions with the facilities personnel have revealed that they can not accept PCB waste. They stated that a TSCA permit is in their future plans but have not yet applied for one.

The Envirocare facility is retained as a feasible location for the final waste disposal since there are PCB treatment processes under consideration which could produce an acceptable waste product.

10.4.7.3.4 Barnwell Waste Management Facility—The disposal criteria for the Barnwell facility was reviewed possible disposition of the tank waste treatment product. This document is Chem-Nuclear's document no. S20-AD-010, Revision 13. In the document it states that "no PCBs or PCB contaminated items will be accepted for disposal" and that treated hazardous waste will be reviewed for acceptance on a case by case basis.

The Barnwell facility is retained as a feasible location for the final waste product disposal since there are PCB treatment processes under consideration which could produce an acceptable waste product.

10.4.7.3.5 Nevada Test Site—The waste acceptance criteria, document NTSWAC (Rev. 0), for the Nevada Test Site states that the PCB concentration must be 50 ppm. The document also reads the low-level waste offered for disposal must not exhibit characteristics of, or be listed as, hazardous waste identified in Title 40 CFR, state of Nevada regulations, or state-of-generation hazardous waste regulations".

The Nevada Test Site is retained as a feasible location for the final waste disposal since there are PCB treatment processes under consideration which could produce an acceptable waste product. In addition the tank waste will be treated for the hazardous constituents.

10.5 References

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